5 Biodiversity

Smart, S.M.[1], Astbury, S[2]., August, T[3]., Botham, M[3]., Cooper, J[1]., Emmett, BA[2]., Goodwin, A[1], Hall, J[2]., Harrower, C.[3], Henrys, P[1]., Isaac, N.[3], Jarvis,S.[1], Maskell, L[1]., Norton, L.[1], Oliver, T[3], Peyton, J[3]., Powney, G[3]., Rorke, S[3]., Rowland, C[1]., Roy, D[3], Scholefield, P[1]., Siriwardena, G[4]., Tebbs, E[1], Wagner, M[3].,Wood, C[1], Beckmann, B[3]., Dadam, D.[4]

[1]CEH Lancaster, [2]CEH Bangor, [3]CEH Wallingford, [4]BTO

5.1 Introduction

The conservation of biodiversity in Wales is motivated by the value people place on a rich heritage of wild species and habitats. Particular habitats and species have a stronghold in Wales whilst being rare or absent elsewhere in the UK and Europe so that Wales has a particular responsibility for their monitoring and conservation. While the importance of biodiversity reflects the values placed on it by people, some of these values are harder to quantify than others. They are nonetheless important, including for example, conservation of wild species and habitats for their cultural, spiritual, aesthetic and recreational importance. In 2007 the Environment Agency Wales estimated that “wildlife-based activity” contributed a total output of £1.9 billion per year to the Welsh economy which exceeded the total agricultural output in 2011 of £1.3 billion (EA Wales 2007). Therefore the contribution of biodiversity to prosperity, well-being and job creation in Wales should not be underestimated.

5.1.1 Policy context

Policy drivers for the conservation of biodiversity in Wales reflect both global to regional trends and the need to engage with the human drivers of these trends. The goal of sustainable rural development within the EU Rural Development Program seeks to achieve economically and ecologically sustainable use of land and water. This recognises a requirement for reversing ecosystem degradation and the loss of underpinning biodiversity. In Wales, the Glastir scheme is a significant component of the Rural Development Program and so contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity. These are derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act). Of particular significance is target 3 of the EUBS that aims to ‘increase the contribution of agriculture and forestry to biodiversity’. Since 81% of Wales is farmed, agri-environment scheme funding is seen as one of the most important mechanisms for delivering a large-scale re-balancing of production, ecosystem service supply and biodiversity to achieve sustainable rural development.

5.1.2 Major achievements in Year 2:

- Proxy habitat indicators developed and species management reviews carried out for all Section 42 species that have been linked to option bundles in Glastir.
- Indicators applied to baseline survey data for six Section 42 species reflecting uptake of their associated options in year 1 and 2 GMEP 1km survey squares.
- New long-term trend indicators completed for birds, butterflies and priority invertebrate species. In the case of birds this is to overcome the limitation of the Farmland Bird Index which can potentially be driven by a trend of just one species.
- Over 30 new derived indicator variables computed for the year 1 and 2 vegetation plot data.
- Extensive analysis of the legacy effects of Tir Gofal and Tir Cynnal completed by BTO using Breeding Bird Survey squares in Wales.

- Headline questions about long term trends in habitat extent, condition, diversity and connectivity answered and web portal entries completed.
- Headline questions about the impact of Glastir addressed by characterizing the status of biodiversity indicators across the year 1 and 2 GMEP 1km survey squares contrasting habitat and features in and out of option.
- New analysis of the relationship between bird species in the GMEP field surveys and coincidence with Glastir management options.

5.1.3 Key Findings in Year 2

5.1.3.1 Long term trends

The overall picture for long term trends in biodiversity is some evidence of recent stability for some elements of biodiversity but little evidence currently of improvement. For example new analysis of long term data from sources such as the UK Butterfly Monitoring Scheme, data held by the Biological Record Centre from a wide range of monitoring programmes and the BTO/JNCC/RSPB Breeding Bird Survey and other bird survey data from a range of sources indicates:

- Composite measures of long term trends in butterfly species abundance in Wales indicates stable populations for wider countryside generalists and stability since 1998 for habitat specialists after a decline between 1976 – 1998.
- A new Priority Invertebrate Species Indicator for Wales based on 87 species with sufficient long term records had sufficient uncertainty which prevented any conclusions.
- Total abundance of target bird species and overall bird diversity is shown to be stable since 1994. It is important to note this type of composite metrics can mask important changes in individual species.
- A newly constructed Priority Bird species Index for 35 species with sufficient trend data available in Wales indicates at least half as increasing or stable since 1994 but with no pattern for an overall improvement in population health over time.

5.1.3.2 Direct assessment of Priority Habitats and Species from the GMEP survey

- From the GMEP survey itself, it is expected there will be sufficient sampling power to report on change in extent for 13 Priority Habitats in the future. Recent trends from analysis of historical data are currently being discussed with NRW.
- There may also be sufficient data for 14 of 50 priority bird species and 7 of 15 priority butterfly species.
- Methods for reporting change in ecological conditions that would be expected to favour other priority species such as the Dormouse and the Lesser Horseshoe Bat are described.

5.1.3.3 Impact of Glastir

Establishing a baseline to track future change is one of the main reasons for establishing GMEP to run alongside the Glastir Scheme from its inception. Analyses indicate how critical this will be if false positives benefits are to be avoided. For example:
Statistically significant higher habitat diversity of land entering the Glastir scheme needs to be included in future analyses.

Current figures from Years 1 & 2 of the 4 year survey indicate sufficient coincidence of uptake of Glastir options and priority species for four of 14 Glastir option types aimed wholly or partly at benefitting birds; marshland, winter food, summer food and woodland to enable direct reporting of bird populations to Glastir options. Critically, initial difference in baseline bird densities of land in and out of scheme are indicated which must be taken into consideration in future analyses of Glastir impact.

5.1.3.4 Impact of past agri-environment schemes

The impact of past agri-environment schemes on birds was assessed using bird population growth rates (changes from year to year) using BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Positive associations with Tir Gofal options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management. The evidence therefore supports broadly positive effects of Tir Gofal, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland.

The legacy effect of Tir Gofal on land coming into the Glastir scheme was also assessed for plant species. Despite these initial small sample sizes as it only includes years 1 and 2, a continued beneficial effect of two options was detected; a) terms of species richness in ungrazed broadleaves woodlands (option 1A) in plots that had entered Tir Gofal before 2006 and b) for the grass:forb ratio (a negative indicator) for upland heath.

5.1.4 Background to approach

GMEP consists of a rolling 4-year cycle of surveys. Analyses that seek to identify the impact of Glastir options on change over time will therefore begin in earnest once the next cycle begins and survey GMEP 1km survey squares are visited for a second time. During the first two years of the first 4-year cycle we have been developing methods for exploring Glastir impacts on Section 42 species determining the coincidence of options with species and habitats and deriving new indices of long term trends in biodiversity as the backdrop to GMEP. We are also developing methods to characterise High Nature Value (HNV) farmland (see chapter 9) and to extend our estimates of biodiversity change and impacts of Glastir outside of the sample of GMEP 1km survey squares and into wider Wales by integration with remotely sensed data products and biological records databases. . For brevity not all national trend data are reported here but are available within the GMEP Data Portal. Data on Priority Habitats extent and condition are not yet available.

5.1.5 Quantifying the impacts of Glastir on Section 42 species

We have developed the knowledge base required to identify sets of proxy indicator variables for Section 42 species and on the derivation of these indicators from GMEP survey data. This comprises comprehensive reviews of species' ecology and establishing how Glastir options targeted at particular species can be matched with performance indicators derived from field survey attributes. These indicators measure whether Glastir options have resulted in ecological changes assumed favourable to Section 42 species populations. Example applications are presented: Taking the most common Section 42 species from each group of organisms, sets of indicator variables were applied to the baseline survey data from years 1 and 2. As the time series grows we will determine whether these indicators diverge between locations in and out of Glastir. The results will show whether expected ecological changes have resulted from Glastir uptake and whether options are likely to have enhanced rare species populations where the two spatially coincide. Example application of indicators to the year 1 and 2 baseline are presented under the headline question '*What is the benefit of Glastir options?'* and have been formatted as they will appear on the GMEP data portal.

5.1.6 Developing high precision ecological indicators back to 1990: Linking GMEP to Countryside Survey

Work has also focussed on linking GMEP survey data for years 1 and 2 to the historical time series provided by Countryside Survey (CS). These analyses contribute to addressing the headline question '*What are the long-term trends in biodiversity in Wales?'* The strength of CS and GMEP is that spatial patterns and change over time can be referenced precisely to habitat types and features, such as hedgerows, watercourse banks and field boundaries, which are targeted by individual options. Examples include quantifying total cover of important nectar-providing plants from vegetation plots located in arable land, broadleaved woodland and neutral grassland going back to 1990. In arable land we also discriminate between the boundaries of arable fields and their interior.

5.1.7 New indices and data to describe long-term trends in Welsh habitats and biodiversity

Changes within CS and GMEP 1km survey squares also need to be set within the context of past biodiversity trends in the wider countryside. New indicators and data are presented exploiting the long-term time series from volunteer-based schemes. Examples are given for butterflies using the UK Butterfly Monitoring Scheme data for Wales. An extensive new analysis has also been undertaken to quantify long-term trends in Welsh breeding birds. This work utilised the BTO Breeding Bird Survey data for Wales. Trends for individual birds are described and then summarised into novel indices of change in Lowland Farmland, Upland Farmland and Woodland birds all based on Wales-only data. We also report progress on the assembly of recent biological records for Section 42 species at 1km resolution. Finally Biological Records Centre (BRC) data holdings have been used to develop a Priority Invertebrate Species Indicator for Wales, which is a Wales-only version of the the UK C4b indicator (http://jncc.defra.gov.uk/page-6850).

Substantial new work has also been carried out to quantify habitat diversity, habitat connectivity, extent and condition of Priority Habitats and Woody Linear Features. A new Woody Cover Product was developed by synthesising existing datasets combined with new analyses to providing a finely resolved map of woody linear features, hedgerows and woodlands across Wales. New habitat connectivity analyses were based on this improved product. These analyses are reported in Appendices 5.10-5.13 and Chapter 4.

5.1.8 Detecting the legacy effect of previous Agri-Environment Schemes (AES) within GMEP 1km survey squares

Two analyses have been carried out to detect the legacy effects of previous AES in Wales. An exhaustive analysis of BTO Breeding Bird Survey Squares has been completed. With the caveat that some rarer target species were not testable because of small sample sizes, the results of this study provide good evidence for broad, positive effects of several aspects of Tir Gofal management, especially that concerning woodland, scrub, hedgerows and arable seed-rich habitats on target bird species. Other management under the scheme has not been so conspicuously successful.
A second analysis searched for legacy effects of Tir Gofal in vegetation plots sampled in the year 1 and 2 GMEP 1km survey squares. Only 3 out of 45 option + habitat + indicator combinations showed any significant difference between locations previously in Tir Gofal versus those never in agreement. Because of the small sample sizes available per option and the restriction to just year 1 and 2 no firm conclusions can be drawn about the magnitude of legacy effects. The analysis will be repeated when year 3 and 4 data are available.

5.1.9 Priority (Section 42) Habitats

Areas of each habitat mapped within year 1 and 2 GMEP 1km survey squares are presented along with assessments of condition indicators for example habitats. A simple method has also been developed for estimating the sample size required to deliver robust estimates of extent given the likely total area of each habitat in Wales.

5.1.10 Remotely sensed data

Work has also been carried out using remotely sensed datasets in combination with field survey data and other spatial map products to estimate landscape and ecosystem attributes across Wales. We report progress calibrating earth observation data with detailed plant trait data to estimate above-ground Net Primary Productivity. We also report production of a woody linear feature map that fills a significant gap in existing land cover mapping. Results from both activities support the identification and mapping of HNV in Wales.

5.1.11 What is covered in this chapter?

This chapter summarises recent progress and future plans for assessment of the impact of the Glastir agri-environment scheme on Welsh biodiversity. We apply a combination of approaches including modelling and analysis of existing biological records and monitoring scheme datasets, and of the new data collected in years 1 and 2 of the 4 year rolling monitoring programme. We demonstrate how we will address two fundamental questions about biodiversity in Wales; what are the long term trends in species and habitats? What will be the impact of Glastir? Because field data are only available from years 1 and 2 of the baseline 4-year roll, answers to these questions focus on quantifying past trends in species abundance as a way of establishing the starting conditions and ecological context for Glastir. The impact of Glastir has also been addressed at this stage by characterising the baseline ecological variation in GMEP 1km survey squares and expressing whether there are any starting differences between land in and out of options taken up in the first two years of the scheme and whether these might reflect the legacy effect of previous schemes. BTO have also carried out new and exhaustive analyses of Tir Gofal and Tir Cynnal legacy effects in their Breeding Bird Survey squares in Wales. The reader is directed to extensive appendices for more detail on all the items summarised in this chapter.

5.2 Biodiversity - current status and trends

5.2.1 Long-term trends in biodiversity in Wales

Recent work has focussed on assembly of species distribution data from established recording schemes to produce new time series of change based on Wales-only data. These new indices are fully described in Appendices 5.3, 5.9 and 5.10.

5.2.1.1 Butterflies

Across the UK, butterfly numbers have declined at least since the 1970's as a result of habitat loss through land converted to agriculture and subsequent intensification. Because insect populations fluctuate annually in response to weather, parasitism, predation and other factors, it is essential to determine patterns over long time series to see how populations are changing when these other effects are accounted for.

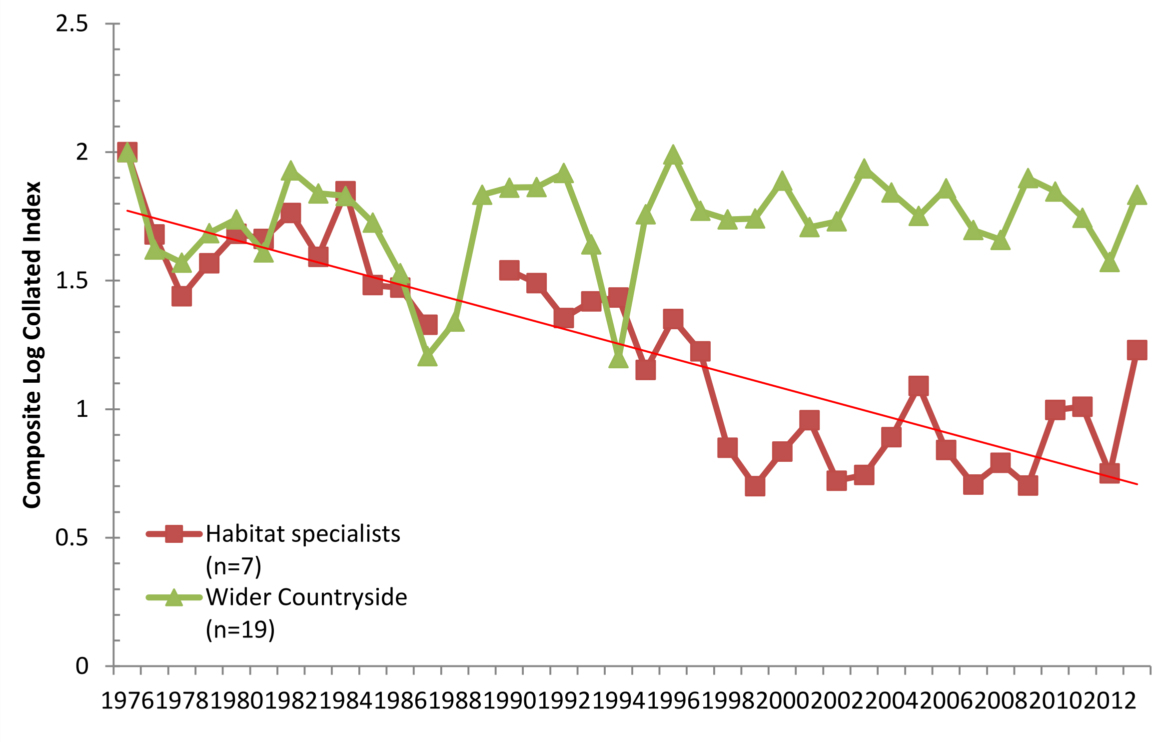


Figure 5.2.1.1.1 *Long term trends in butterfly species in Wales (UKBMS data).Wider countryside species trends were calculated from 207 sites (121 of these being WCBS 1km squares) and Habitat specialists from 121 sites (98 of these are non-transect sites (timed counts and larval web searches)). See Appendix 5.10 for further details.*

UK Butterfly Monitoring Scheme (UKBMS) data is shown for Wales going back to 1976 (Fig 5.2.1.1.1). Butterfly species abundance in 319 sites (comprising 91 standard BMS transects, 107 non-transect sites (these are timed counts and larval web counts), and 107 WCBS 1km squares) has been collated and trend lines are shown for two groups: Wider countryside species trends are derived from all the data including WCBS 1km squares. Wider Countryside species include generalists such as Meadow Brown (*Maniola jurtina*), Large White (*Pieris brassicae*) and Peacock (*Aglais io*), whose larvae feed on forbs and grasses abundant in productive farmland. These species are therefore able to survive better in the modern countryside and show a stable pattern with fluctuations reflecting the influence of the weather on population size. Habitat specialist trends are based only on BMS transect and non-transect data. Habitat specialist species such as Pearl-bordered (*Boloria euphrosyne*), High Brown (*Argynnis adippe*) Fritillaries, and the Grayling (*Hipparchia semele*) show greater restriction to less productive semi-natural habitats such as heathland and fen. The index for these species shows a rapid and highly significant decline in Wales since 1976, and appearing to stabilise at a lower abundance after 1998.

5.2.1.2 Wales-only version of the C4b Priority Invertebrate Species Indicator

A Wales-only version of this indicator was developed to allow direct comparison with the existing UK-wide version. The derivation of the indicator mirrors the approach applied at UK level (http://jncc.defra.gov.uk/page-6850) but uses data from Wales only. The indicator utilises opportunistic biological records to examine the long-term trends in priority invertebrate species in Wales. Species covered by other established recording schemes – birds, bats, plants - or where reliable data does not exist for the time period were excluded.

The priority invertebrate species indicator (Figure 5.2.1.2.1) illustrates the change in frequency of occurrence of well-recorded priority species in Wales between 1970 and 2010. The indicator was created by combining the annual frequency of occurrence estimates of 87 species, the majority of which are moths (81 moths, 1 dragonfly and 6 bee species). This number is smaller than the 179 species that contribute to UK Priority Species Indicator C4b, reflecting two differences between the UK and Wales versions of the indicators: 1) the UK indicator includes species that are considered priorities in England, Scotland and Northern Ireland, whereas the version presented here is restricted to Section 42 species (i.e. the Welsh priority list). 2) Some species had insufficient data to estimate their status in Wales. The indicator shows a marginal decline across all species, however the 95% confidence intervals surrounding the trend are large and span zero. Consequently there is considerable uncertainty in the status of these specific invertebrate priority species at the present time. See GMEP Year 1 report for more information on how this is calculated (Emmett et al. 2014).

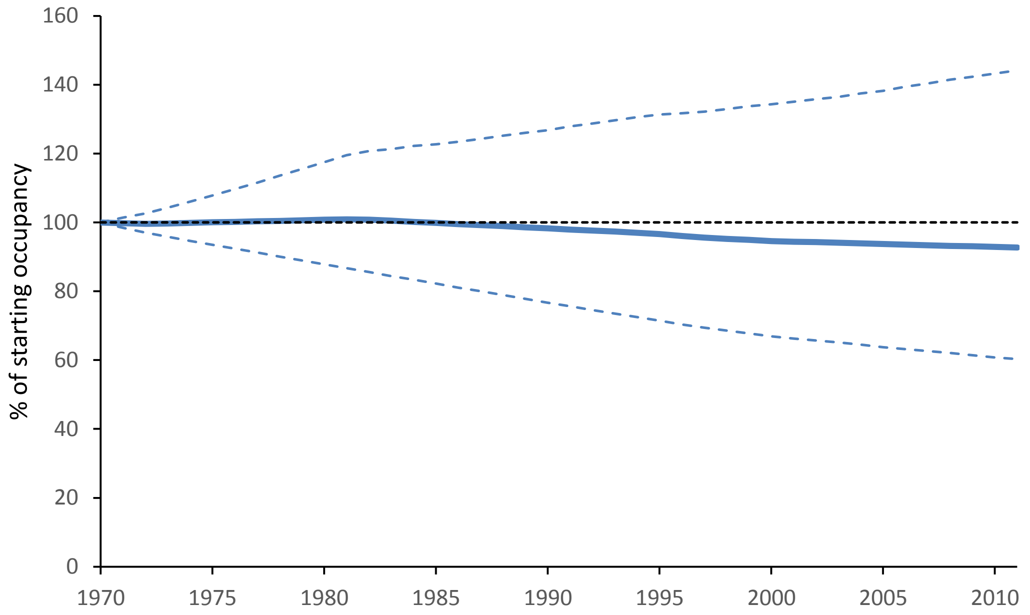


Figure 5.2.1.2.1 *Long term trends in 1km occupancy of priority invertebrate species based on Wales-only records. 95% Confidence Intervals around the trend line are shown. These diverge rapidly as variation in individual species trends reduces the influence of all abundances being centred at 100 at time 0. See Appendices 5.9 and 5.10 for details.*

These results are different from the draft indicator initially tested and presented in the year 1 report. This is because additional records for more species were added in the last year following the acquisition of new datasets. CEH is currently improving the methodology underpinning UK indicator C4b, and greatly expanding the taxonomic breadth of species that contribute to it. If this work were extended to the Welsh data for Section 42 species it would generate an indicator trend with considerably reduced uncertainty. The derivation of this indicator will also change in the next few years resulting in improvements in the way the indicator accounts for variation in recorder effort between locations and years. Additionally, we are developing ways to include covariates (such as Glastir option uptake) into the Bayesian occupancy models enabling us to test hypotheses about the impact of scheme management on occurrence trends (see Appendix 5.9). The ultimate aim is therefore to explore how future trends in many species might be influenced by scheme effects in all 1km squares not just those in the GMEP sample. This offers a complementary perspective to the GMEP analyses. The major strength of the latter is that Glastir effects can be sought by targeting specific combinations of option, habitat and landscape feature with high spatial precision within 1km squares.

5.2.1.3 Long-term trends in Welsh breeding bird populations

Patterns of long-term population change among Welsh birds are of considerable interest to identify both where there are specific conservation issues for Wales and where population trends are more positive or more negative than elsewhere. They are also critical to enable the Welsh Government to report on progress towards national and international biodiversity targets. GMEP field surveys are designed to deliver integrated, ecosystem-level monitoring complementing other monitoring in Wales. Thus, high intensity monitoring in GMEP is traded off against annual spatial coverage and sampling frequency. For birds, lower intensity, annual repeat sampling of a larger number of squares is provided by the BTO/JNCC/RSPB Breeding Bird Survey (BBS), as well as various bespoke monitoring for rarer species. These data are collated and reported annually within GMEP, primarily via the online portal (see Appendix 5.3).

Species-specific population trends reflect differences in ecology and are critical for understanding causes of change, so the primary focus of the regular reporting online is on species-specific trends. However, multi-species summary indices are useful to represent common patterns across communities or habitats, or to test specific hypotheses, so they are presented here and on the GMEP portal for information. In particular, the multi-species average trends that make up the Farmland Bird Index and related indicators at the UK level (Gregory et al. 2008) are also integrated into reporting at the European level. Wales-specific trends in these indices are, therefore, presented here: the Upland and Lowland Farmland Bird Index and the Woodland Bird Index.

The Farmland Bird Index is based on annual BBS indices for the component species, which include species with a range of prevailing population trends and omit those with smaller BBS sample sizes and those that the BBS does not sample effectively at all. Given that the latter, by definition, include many rarer species, a range of priority species for conservation are not considered in the index. In addition, increasing trends in the index can, in principle, be generated by increasing trends in just one species (say, woodpigeon), while all the others decline. This is clearly an undesirable property in an index used to assess conservation success.

As a result of the above, GMEP is producing further indices to monitor bird populations in Wales, including priority species in particular, which are then reported via the data portal. These are (i) average annual total abundance of target species per BBS square, (ii) average annual Simpson's diversity index across all bird species recorded in BBS squares, (iii) the mean total count of target species in GMEP 1km survey squares each year, (iv) average annual Simpson's diversity index across all bird species recorded in GMEP 1km survey squares and (v) the number of target species whose populations in Wales are stable or increasing, determined from the best available survey data, in five-year blocks. "Target species" are defined as those identified as Section 42 priorities (Table 5.2.4.3.1), excluding those that do not breed in Wales or that are effectively extinct.

5.2.1.3.1 Farmland and Woodland Bird Indices

The BBS is a volunteer survey conducted annually in a random sample of 1km squares across Wales using standardized methods (note that countryside closure due to a foot-and-mouth disease outbreak severely restricted survey coverage in 2001, so results for this year are not reported in some analyses). Counts of individual species from each square are analysed annually to update long-term trends using a standard approach (log-linear Poisson models), with confidence intervals estimated by bootstrapping by survey square. This approach was taken to produce the trends used in annual reporting (Appendix 5.3). Multi-species indices are constructed as annual geometric mean population indices across the species considered, where the indices are back-transformed categorical year effects from species-specific models. These indices are already in use by WG as indicators and are published annually. They are reproduced here as requested by the GMEP Advisory Group.

Summary trends for the multi-species indices for birds in Wales to 2013 are shown in Figure 5.2.1.3.1.1 for farmland (all species and divided into lowland upland species) and woodland, as derived from BBS data. The species sets used and percentage population changes over the whole BBS period are then listed in Table 5.2.1.3.1.1. BBS sample sizes have varied by species and over time, with some turnover as volunteer observers leave and join the scheme. However, active recruitment of surveyors has increased sample sizes for species that are not declining and new observers are sought for squares that drop out of the scheme, so long-term change in the survey coverage is lower than the annual changes in Table 5.2.1.3.1.1 suggest. Moreover, mean turnover across species is 13.3% after 2000, compared to 15.8% for the complete range of years shown in Table 5.2.1.3.1.1.

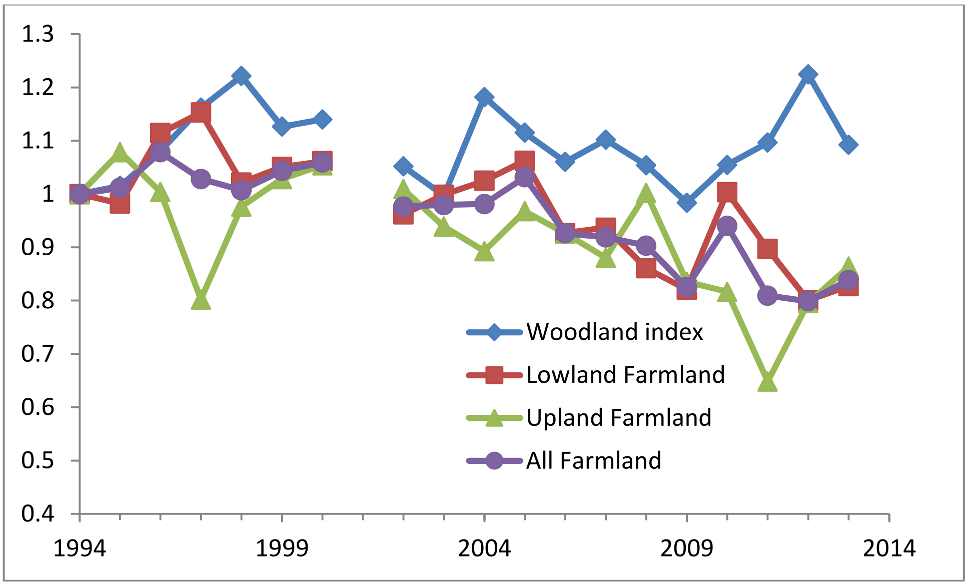


Figure 5.2.1.3.1.1 *Summary index trends for farmland (all species), lowland farmland, upland farmland and woodland in Wales. See Table 5.2.1.3.1.1 for lists of component species.*

Species	Indicator	Annual number of BBS squares with non-zero counts					Notes/ direction of significant change
		Mean	Min	Max	Turnover	% Index Change 1994-2013	
Blackbird	Woodland	197	102	269	17.8	35.2	Increase
Blackcap	Woodland	124	50	182	16.5	123.3	Increase
Blue Tit	Woodland	178	98	233	15.0	13.4	Increase
Bullfinch	Woodland	63	35	89	17.5	-27.8	
Buzzard	Upland Farmland	141	76	188	16.9	-10.1	
Chaffinch	Woodland	198	106	261	17.0	-11.6	
Chiffchaff	Woodland	140	65	208	17.8	52.5	Increase
Coal Tit	Woodland	74	35	93	15.9	-35.3	
Curlew	Upland Farmland	35	18	47	13.6	-55.6	Decline
Dunnock	Woodland	153	78	216	17.3	18.9	Increase
Garden Warbler	Woodland	57	34	62	12.9	-26.8	Increase
Goldcrest	Woodland	81	46	106	16.3	-48.6	Decline
Goldfinch	Lowland Farmland	128	59	176	13.8	73.7	Increase
Great Spotted Woodpecker	Woodland	79	26	130	17.8	208.1	
Great Tit	Woodland	171	88	226	17.1	52.2	Increase
Green Woodpecker	Woodland	46	24	63	15.9	-23.7	
Greenfinch	Lowland Farmland	112	46	152	17.3	-38.7	
Grey Wagtail	Upland Farmland	24	9	32	14.8	-19.9	Small sample
Jay	Woodland	74	25	102	15.5	30.8	Increase
Jackdaw	Lowland Farmland	139	73	179	17.6	38.3	
Kestrel	Lowland Farmland	22	9	29	15.5	-71.3	Small sample
Lesser Redpoll	Woodland	23	10	39	15.8	199.3	Small sample
Linnet	Lowland Farmland	91	49	117	14.4	-25.8	Decline
Long-tailed Tit	Woodland	60	30	84	15.3	22.3	
Meadow Pipit	Upland Farmland	87	51	115	17.3	-6.4	
Nuthatch	Woodland	71	33	94	16.2	47.3	Increase
Pied Flycatcher	Woodland	22	12	26	13.9	-48.9	Small sample
Raven	Upland Farmland	90	42	124	17.9	26.9	
Redstart	Woodland	59	41	92	14.3	31.8	Increase
Reed Bunting	Lowland Farmland	28	9	39	15.4	52.2	Small sample
Robin	Woodland	193	106	260	16.2	-16.8	Decline
Rook	Lowland Farmland	78	46	93	15.6	-9.1	
Siskin	Woodland	27	9	50	17.1	79.6	Small sample
Skylark	Lowland Farmland	103	63	127	13.3	-11.6	
Song Thrush	Woodland	167	83	220	12.1	3.6	
Sparrowhawk	Woodland	21	5	30	15.9	-12.3	Small sample
Spotted Flycatcher	Woodland	23	11	29	13.0	-23.7	Small sample
Starling	Lowland Farmland	79	50	99	13.9	-73.0	Decline
Stock Dove	Lowland Farmland	31	12	41	17.2	132.9	

Tree Pipit	Woodland	33	18	45	14.7	-12.2	
Treecreeper	Woodland	40	22	49	13.6	57.6	
Wheatear	Upland Farmland	53	27	81	17.2	9.5	
Whitethroat	Lowland Farmland	83	39	108	16.1	-2.4	
Willow Warbler	Woodland	160	100	201	13.9	-10.7	
Wood Warbler	Woodland	19	9	25	17.4	-32.3	Small sample
Woodpigeon	Lowland Farmland	188	105	252	17.6	10.8	Increase
Wren	Woodland	197	104	263	17.1	-9.3	
Yellowhammer	Lowland Farmland	34	19	42	15.0	-67.3	Decline

Table 5.2.1.3.1.1 *Species-specific changes in Welsh BBS population indices for the birds included in the summary trends shown in Fig. 5.2.1.3.1.1. Indicator habitat classifications are those used in the standard annual reporting of average trend indicators in Wales. Turnover is defined as the average percentage of squares surveyed in a given year that were not surveyed in the previous year. Detailed trends are shown in Appendix 5.3*

5.2.1.3.2 Diversity and total abundance of target species

High-level indices aiming to summarize broad variation in bird communities in Wales were requested and agreed by the GMEP Advisory Group and are described here. These indices necessarily average over significant variation in patterns of change in abundance of individual species. They also ignore subtleties in the conservation implications of changes in numbers, such as whether increases and decreases in different species' numbers are equally desirable. They should, therefore, be interpreted with care and finer divisions of the data, such as habitat-specific indices or population trends for individual species, should be investigated in making policy decisions.

Count data for all species recorded were extracted from BBS squares and the maximum counts per visit summed across all target species for all BBS squares in Wales in all years. These data were then used to calculate Simpson's diversity index for the entire bird assemblage recorded in the square each year and the total abundance of all target species recorded in the square. Temporal trends in these indices were estimated using a linear model with categorical site and year effects, thus accounting for variation in the composition of the BBS sample (due to survey square turnover) from year to year. The outputs were annual average index values for Wales, which were then plotted and summarized in five-year blocks.

For GMEP 1km survey squares, the total abundance of target species and Simpson's diversity of all bird species were calculated from the maximum counts across visits for GMEP 1km survey squares exactly as described above for BBS squares. Square-specific values were then simply averaged across the two survey years. GMEP surveys cover a different set of 1km survey squares each year, so it is important to recognise that some variation between years is likely to be spatial, rather than temporal. Separation of temporal from spatial variation will begin to be possible after the fifth year of GMEP, when GMEP 1km survey squares from year one are resurveyed.

The total abundance of target bird species in BBS squares has shown little variation over time (Figure 5.2.1.3.2.1). The analogous numbers found in GMEP 1km survey squares were rather more variable across the two years surveyed to date (and is not surprising given the complete change in sample from year to year, in contrast to the large proportion of annual repeats under the BBS), but the confidence interval for both years overlap almost all annual confidence intervals from the BBS. A mean total abundance of target species in GMEP 1km survey squares was 19.11 (SE 3.12) in 2013 and 37.48 (SE 4.58) in 2014. The mean Simpson's diversity index per GMEP 1km survey square was 0.961 (SE 0.006) in 2013 and 0.945 (SE 0.006) in 2014.

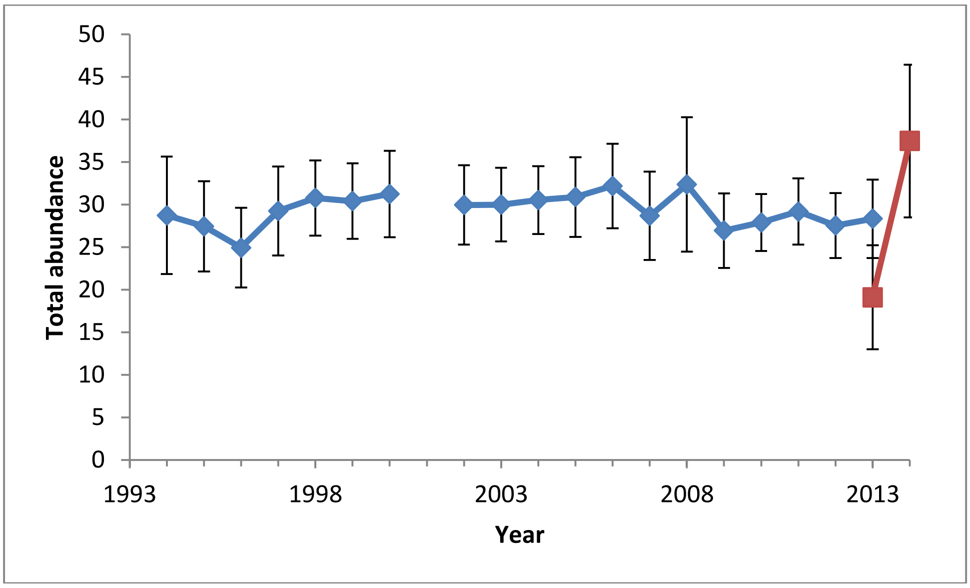


Figure 5.2.1.3.2.1 *Long-term trend in the total abundance of target species from the BBS (blue) and GMEP 1km survey squares (red).Error bars show 95% confidence intervals.*

Simpson's diversity index across all bird species in BBS squares was also rather constant over time, but shows a trend for slight increase since the mid-2000s (Figure 5.2.1.3.2.2). The diversity in GMEP 1km survey squares varied considerably between years, as with total abundance of target species, again probably reflecting differences in the sample of GMEP 1km survey squares from year to year. The diversity index values were significantly higher (Figure 5.2.1.3.2.2), however, showing the detection of more species at low levels of local abundance in the more intensive GMEP surveys.
It is important to note that the indices in this section are very high-level summaries that are rather insensitive to changes in the environment and are certain to mask much variation in the data for individual species and habitats. It is impossible to find single indices that include information on multiple species and habitats, are sensitive to variation in these component parts and are widely representative. Hence, it would be unwise to interpret lack of change in these indices, in particular, as showing stability in all features of interest.

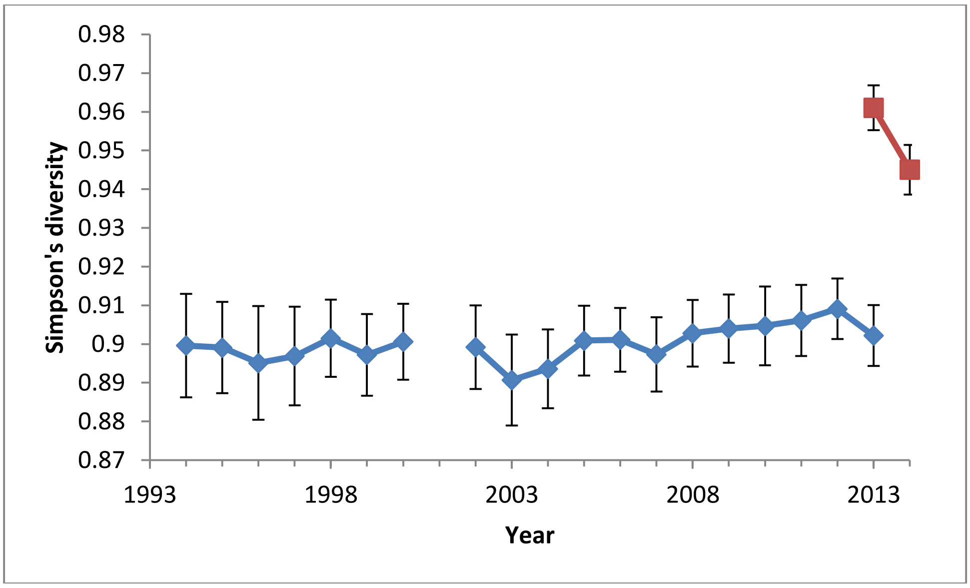


Figure 5.2.1.3.2.2 *Long-term trend in the Simpson's diversity across all bird species from the BBS (blue) and GMEP 1km survey squares (red). Error bars show 95% confidence intervals.*

5.2.1.3.3 Calculating population trends among target species

The available information on trends of species not monitored by the BBS is collated annually within GMEP, together with the relevant BBS data. Full details are presented in Appendix 5.3. The data considered vary in quality (standardisation of recording, frequency of repeat monitoring, geographical extent and representativeness of cover), but are the best available for each species. As well as those for which BBS trends are reported regularly elsewhere, a range of species are included for which the available BBS sample size is below the standard minimum threshold of 30 squares per annum. These population trends are less reliable, but the associated uncertainty in the temporal trends is reflected in their confidence intervals (because there is no reason to expect sampling bias in the random sample of BBS squares) and the sample size problem is highlighted. Note that, as for more common species, trends are presented as smoothed and unsmoothed annual indices. The unsmoothed data include fluctuations from year to year caused predominantly by weather effects on actual numbers or counts in the field. The smoothing process aims to remove these fluctuations to focus on the long-term change that is both a sound reason for cause for concern (where negative) and a rational measure of management impact (where positive). For species not covered at all by BBS, indices are calculated from data from other sources wherever possible. For breeding waterbirds with the most significant populations around large waterbodies (Black-headed Gull, Herring Gull and Ringed Plover), indices are calculated from Wetland Bird Survey (WeBS) data for April-June each year (see Appendix 5.3). For wintering waterbirds for which the Section 42 status is derived from winter populations, indices are calculated from winter WeBS trends (Appendix 5.3). For Chough, data from independent, ongoing, annual survey work will be collated and presented in the same way as the BBS data. These results will be included in the next GMEP report in September 2015. For Twite, Golden Plover, Hawfinch, Hen Harrier, Ring Ouzel, Tree Sparrow, Turtle Dove and Yellow Wagtail**,** data have been extracted from the annual "Birds in Wales" report that constitute county-specific counts of breeding birds. These data were then analysed similarly to the BBS data, using linear models of county and year. The data are unstructured and unstandardized, but should reveal gross changes in abundance within the time-frame considered and represent the best data available. It is intended that these analyses will be improved over time by integrating additional data sources as they are made available, for example including RSPB- or NRW-funded survey data and counts derived from individual, bespoke projects. Currently, the sensitivity and reliability of these analyses are unknown and likely to vary between species; further research using simulation or new field monitoring would be required to inform about these considerations. In the absence of such supporting evidence, the patterns revealed should be interpreted merely qualitatively (i.e. as providing evidence of change or not) and with caution, because the qualitative conclusions could be misleading.

Of 50 priority (Section 42) species, trend data were available for 35. To this number, data for Chough, Black Grouse and Hen Harrier are expected to be added once they are available from independent observers or RSPB. The estimates of trends for Golden Plover, Twite and perhaps other species currently dependent on Bird Report data may also be improved by the addition of available data from formal surveys. The other species for which trends were not available include Nightjar (nocturnal and poorly surveyed), five (now) very rare species that are not well-recorded in Bird Reports (Hen Harrier, Lesser Spotted Woodpecker, Grey Partridge, Red Grouse and Willow Tit) and six species that are now effectively extinct in Wales (Aquatic Warbler, Bittern, Corn Bunting, Corncrake, Red-backed Shrike and Woodlark).

5.2.1.3.4 Constructing a priority bird species index

A summary index of the numbers of priority species showing different population trends, considering all species and all forms of trend analysis described above, was constructed for five-year blocks aligned to those used for averaging multi-species average trend indices. For each five-year period, the trend for each priority species revealed by the best source available (as described above)

was assessed as increasing or stable (score=1) or declining (score=0), using expert judgement. Ideally, a finer definition of trend direction would be used, such as considering rates of decline or increase, or separating "increasing" from "stable", but such categorizations of non-linear trends are difficult to standardize, so fewer categories reduce the potential for subjective variation, and lack of decline reflects the broad policy targets for most species. For the rare species with trends constructed from bird report data, linear trends were fitted and the qualitative pattern revealed for the complete time series available was used to determine scores for all five-year periods. The assessment considered the statistical confidence associated with each trend, but was not bound by it; thus, species showing some evidence of decline or increase that was supported by general conservation opinion and/or trends in the wider UK were assessed as having this population trend direction, even if the pattern was not statistically significant in Wales because of small sample sizes,. This avoided a perverse result wherein conservation-priority species might be given an assessment of population stability simply because they were too rare to be monitored with high precision. A measure of the overall health of the populations of priority species was then provided by the number, or percentage, of them that were assessed as having a score of 1. Percentages were used to account for the fact that data were not available for all species of interest in all time periods and "no data" does not represent decline or increase/stability without assumptions that potentially introduce bias. A total score at its maximum value (reported as a percentage, so 100%) would indicate that all species of concern were at least stable, while increases towards this total over time would indicate that the direction of travel of was showing progress towards meeting of conservation priorities. The process of constructing this index was conducted using the trends shown in Appendix 5.3 and the matrix of estimated trend scores is provided in Annex 4 for transparency. In the future, it would be wise to undertake the scoring process using multiple experts, perhaps using a Delphi procedure to arrive at final outcomes, but resources did not permit this in the current project.
The numbers of species available for summarizing trends in different five-year blocks varied slightly because wintering Bewick's Swans effectively disappeared from Wales after c. 2002-03, so this species contributes to the ultimate index only before this time, wintering Greenland Greater White-fronted Goose has been monitored only since 2000, so there were no data to contribute to the first time period and reliable Hen Harrier change information is available (from an RSPB survey, Hayhow et al. 2013) only for 2004-11. Otherwise, trends were scored as increasing/stable or declining and the results across species were as summarized as percentages in Table 5.2.1.3.4.1.

	1994-1999	**2000-2004**	**2005-2009**	**2010-2014**
Number of species with trend data	34	35	35	34
Number increasing/stable	23	21	17	22
Percentage increasing/stable	67.6	60.0	48.6	64.7

Table 5.2.1.3.4.1 *Summary of population trends across priority (Section 42) species.*

At least half of the priority species were scored as increasing or stable in each of the periods considered, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time.

5.2.1.3.5 Overall conclusions regarding the long-term trends in Welsh breeding bird populations

Patterns of population change in birds are likely broadly to reflect the health of other groups at large spatial scales, as well as habitat quality, because birds are near the top of the food chain and depend upon these components of the environment. Therefore, large changes in the summary indicators in Figure 5.2.1.3.1.1 are likely to be associated with changes in other biodiversity. Note, however, that there is no evidence for specific relationships between these indicator values and indicators of other taxa.

In general, the Welsh farmland bird indices show a tendency to declines from around 2000, while the woodland index has remained relatively stable (Figure 5.2.1.3.1.1). This reflects the continuing downward trends in a number of farmland bird species, such as Yellowhammer and Skylark.
It is important to note that the multi-species indicators are simply average trends; they are intrinsically trade-offs between component species and positive or negative changes cannot be interpreted as showing that all share the overall pattern. It is very likely that the overall average masks diverse species-specific patterns, some of which are clear from the long-term changes summarized in Table 5.2.1.3.1.1. Therefore, within a declining indicator, it is likely that some component species will need no conservation action, but declining species may feature within an increasing trend and thus be conservation priorities. As a result, it will always be advisable to refer to the trends of individual species, as shown in the Welsh Bird Trends summary document (see Appendix 5.3) when making conservation decisions.

The total abundance of target species and overall species diversity show different patterns over time (Figures 5.2.1.3.2.1 and 5.2.1.3.2.2), although neither shows the clear pattern of increase that would be indicative of generally increasing bird populations. As with other indicators, however, the process of summarization will have masked some patterns of relative increase for individual species, while masking others of relative decline for other species.

The index of overall health of population trends of priority species consisting of the percentage that are increasing or stable is attractive in that it is easy to understand and that it reflects directly what most conservationists and policy-makers will be concerned about, namely whether populations of species of interest are in decline or not. It also implicitly weights all species equally, unlike the average trend approach, which allows more variable species to influence the outcome more. Unlike the specific average trends in use at the Wales, UK and EU levels (Gregory et al. 2008), this index also considers only priority species, so that the outputs cannot be influenced by changes in the populations of common (or even pest) species (e.g. Woodpigeon). Clearly, the species list included can readily be revised, subject to data availability. Weaknesses with the approach include that it inevitably incorporates a degree of subjectivity because it would be unwise to consider only statistically significant changes, given the sample size (and power) constraints inherent in assessing rare or declining species. Data on rarer species are also often less reliable or unavailable, when these may be both the highest priority and the most targeted by conservation action, and therefore the most critical for monitoring. Finally, it would be difficult to introduce this approach at a temporal resolution of less than five years or so, so the index will not respond rapidly to environmental change or management. Finer temporal resolution for presentation purposes could be achieved by using a five-year (say) moving window to evaluate trends for individual years, but the influence of multiple years on the trend estimate for any given time point would still entail a slow response to external drivers. With those caveats in mind, overall the results indicated at least half of the priority species were scored as increasing or stable in each of the periods considered, but there was considerable variation in trend direction within and between species, leading to considerable variation in the overall index of population trend health. Specifically, rather more population trends were negative during 2000-2009 than at either end of the time series considered and there was no pattern for an overall improvement in population health over time.

5.2.2 Priority Habitats

5.2.2.1 Introduction

There are a number of habitats of principle importance to conservation in Wales which are known as 'Priority' habitats or Section 42 habitats. The production of a Section 42 list is a requirement of the Natural Environment and Rural Communities Act 2006, and is used to guide and prioritise future conservation action in Wales. Some of these priority habitats are specifically mentioned as targets in

Glastir e.g. Lowland heathland, wetland and there are options in the scheme designed to optimise management to ensure that they are in good condition. Many of these habitats are important to priority and Section 42 species and management and creation options in Glastir are designed to benefit them. In GMEP, priority and Broad Habitats are mapped in every GMEP 1km survey square, this includes large areas of habitat e.g. blanket bog but also linear features such as streamsides, hedgerows and belts of trees. How many priority habitats are sampled in the GMEP field survey and how many Priority habitats coincide with Glastir agreement maps by the end of year 2? This question addresses the number and type of priority and Broad Habitats surveyed in GMEP and examines the proportion of mapped habitat that coincide with Glastir uptake to date.

5.2.2.2 Methods

In the GMEP field survey the habitats and features of every GMEP 1km survey square are mapped using a bespoke GIS software system on field computers. As well as classifying each habitat type using a vegetation key many detailed attributes are recorded such as the height of the vegetation, the species composition, the management and use and the condition. This gives us a detailed complex database that can be queried to determine how habitats and features vary spatially and how they are changing and how they are influenced by management actions. It is also valuable information to contribute to studies of priority species.

5.2.2.3 Results

Figure 5.2.2.3.1 shows the % of the GMEP 1km survey square area attributed to different habitat types.

The most commonly surveyed habitats are the Broad Habitats improved, neutral (largely semi-improved) and acid grasslands and coniferous and Broadleaved woodland. These make up a large proportion of the Welsh countryside. The most frequently surveyed priority habitats include Purple Moor-grass and Rush Pasture, Upland Heath, Blanket Bog and some of the woodland priority habitats wet woodland and Lowland Mixed Deciduous. Most of the priority habitat types are recorded in the GMEP survey but some make up a very low percentage of the survey. Upland habitats are better represented in the targeted GMEP 1km survey squares which is to be expected as these were chosen to reflect the Welsh Government priorities in the first two years of Carbon and water. Condition assessments of a subset of these Priority Habitats are reported in the GMEP Data Portal.

Figure 5.2.2.3.2 shows the percentage of the total area of different habitats in Wales GMEP year 1 and 2 1km survey squares that are currently under a Glastir scheme. Acid, calcareous and marshy grassland (includes Purple Moor-grass and Rush Pasture) are well covered by Glastir agreements as are bogs, mires and heathlands. Woodland habitats are less well covered with only 22.7 % of semi-natural broadleaved woodland being under Glastir agreement.

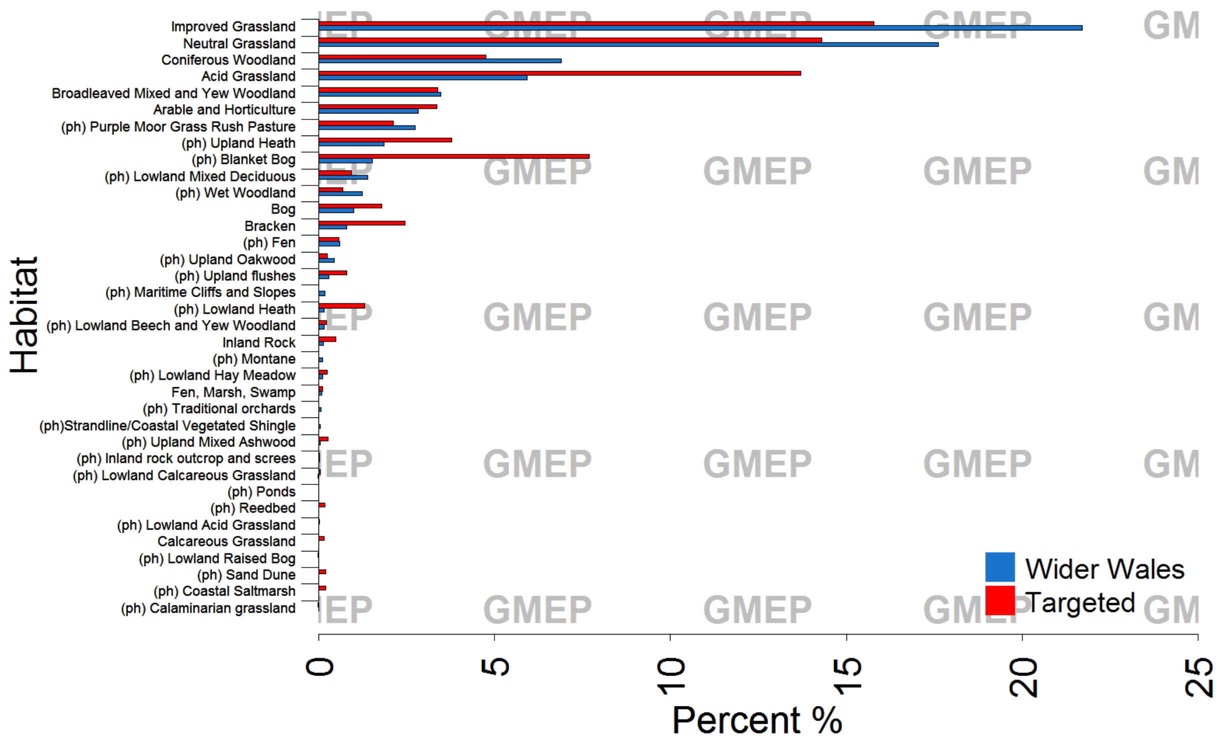


Figure 5.2.2.3.1 *Percentage of the area surveyed in the GMEP field survey in year 1 and 2 GMEP 1km survey squares. The Broad Habitat figures do not include those areas also identified as priority habitat (ph).*

Habitat	%WW	%Targeted
Improved Grassland	21.7	15.77
Neutral Grassland	17.61	14.29
Coniferous Woodland	6.91	4.76
Acid Grassland	5.93	13.7
Broadleaved Mixed and Yew Woodland	3.47	3.38
Arable and Horticulture	2.83	3.37
(ph) Purple Moor-grass and Rush Pasture	2.74	2.13
(ph) Upland Heath	1.86	3.79
(ph) Blanket Bog	1.53	7.7
(ph) Lowland Mixed Deciduous	1.4	0.93
(ph) Wet Woodland	1.25	0.7
Bog	1.01	1.79
Bracken	0.81	2.47
(ph) Fen	0.61	0.58
(ph) Upland Oakwood	0.45	0.25
(ph) Upland flushes	0.3	0.81
Standing Open Waters and Canals	0.2	1.32
(ph) Maritime Cliffs and Slopes	0.19	0.01
(ph) Lowland Heath	0.16	1.31
(ph) Lowland Beech and Yew Woodland	0.16	0.23
Inland Rock	0.15	0.5
Rivers and Streams	0.14	0.19
(ph) Montane	0.13	0
(ph) Lowland Hay Meadow	0.12	0.26

Fen, Marsh, Swamp	0.1	0.12
(ph) Traditional orchards	0.07	0.01
(ph)Strandline/Coastal Vegetated Shingle	0.05	0.01
(ph) Upland Mixed Ashwood	0.05	0.27
(ph) Inland rock outcrop and screes	0.03	0.03
(ph) Lowland Calcareous Grassland	0.02	0.05
(ph) Ponds	0.01	0.01
(ph) Reedbed	0	0.19
(ph) Lowland Acid Grassland	0	0.04
Calcareous Grassland	0	0.16
ph) Lowland Raised Bog	0	0.02
ph) Sand Dune	0	0.2
(ph) Coastal Saltmarsh	0	0.22
(ph) Calaminarian grassland	0	0.02

Table 5.2.2.3.1 *Data from GMEP field survey showing the coverage of different Broad and Priority habitats (ph) as a % of the total area surveyed.*

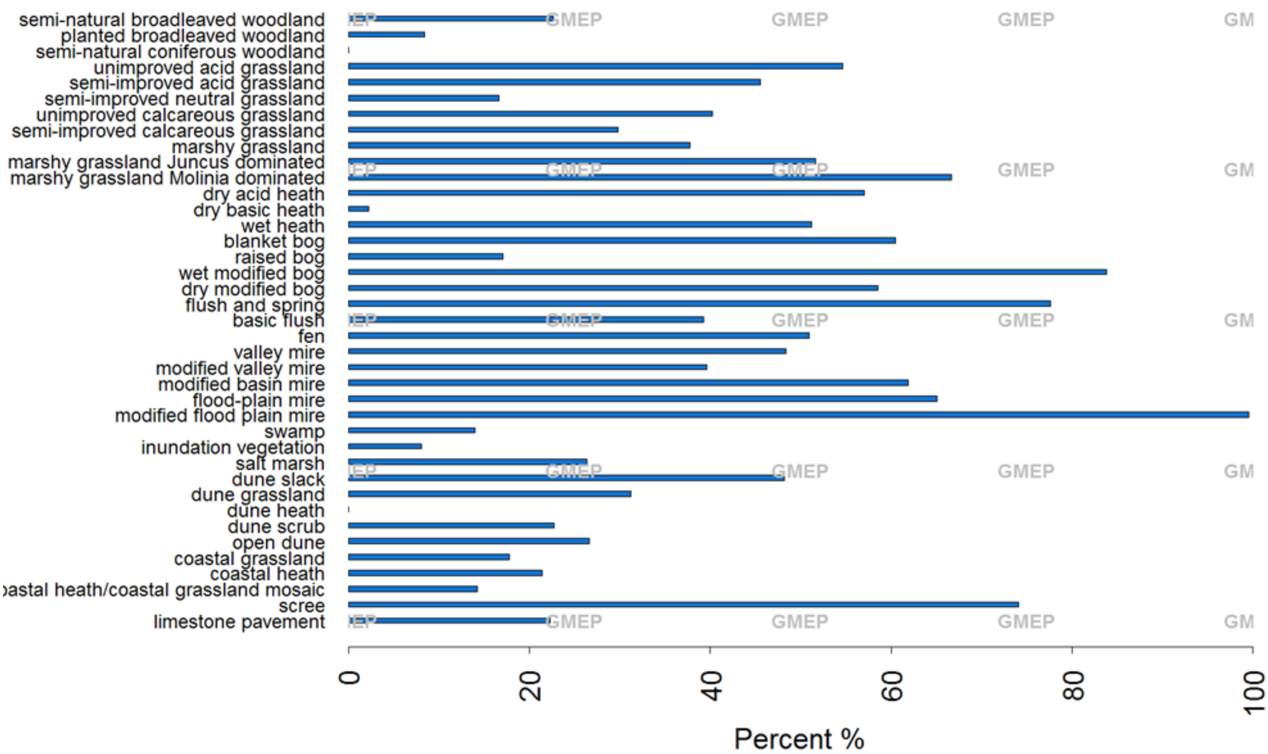


Figure 5.2.2.3.1 *Percentage of total area of each habitat in the whole of Wales covered by a Glastir scheme (includes all schemes, entry, advanced, Woodland element, commons, GEG) and uses NRW Phase 1 survey data to represent habitat coverage.*

5.2.2.4 Estimation of national stock and change in extent and Glastir impacts on Section 42 habitats

Using existing estimates of the extent of Section 42 habitats in Wales and mapped extent of habitats through years 3 and 4, we will be able to determine for which of these habitats the GMEP field survey will yield estimates of stock and change with different levels of uncertainty attached. These uncertainties reflect sample size (number of GMEP 1km survey squares surveyed) and the variation between GMEP 1km survey squares in the coverage of each habitat. An example of this approach is shown below for two habitats. The uncertainty around the sample-based estimate of extent is expressed by the Coefficient of Variation (CV) (the standard deviation as a percentage of the mean). The example below shows the CV for two habitat areas of 2000ha and 20000ha over the whole of Wales). We do not currently have sufficient sample size for the smaller area (Figure 5.2.4.4.1a) as the current sample size after 2 years (red line) only provides a coefficient of variation of just over 25%. By the end of the roll (blue line) we should have sufficient sample size. For the larger area (Figure 5.2.4.4.1b) we already have enough GMEP 1km survey squares to report on the area of the habitat with sufficient confidence. The next stage is to use the observed habitat areas surveyed in years 1 and 2 plus national estimates for the rarer habitats not yet encountered and use these data to initially estimate the levels of power achievable for reporting stock and change in extent likely over the 4 year roll. The importance of using prior information on the distribution of each habitat is that the estimation of power needs to account for the deviation of the distribution of habitats from a random spread. For example coastal habitats are likely to require a separate stratification to achieve robust estimation. At present survey squares are optimised for sampling Glastir in conjunction with the wider countryside reflecting the principal objective of GMEP.

Currently we anticipate being able to report on change in extent for 13 priority habitats (0f 36 terrestrial and freshwater priority habitats): Blanket bog; Upland heath; Lowland Heath; Purple Moor-grass and Rush Pasture; Fen; Upland flushes; Ponds; Lowland Mixed deciduous woodland; Wet Woodland; Lowland Beech and Yew Woodland; Upland Oak Wood; Upland mixed Ashwood; Hedgerows. Change for condition may be possible for: Arable field margins; Upland heath; Lowland Heath; Purple Moor-grass and Rush Pasture; Lowland Acid Grassland; Lowland Hay Meadow; Upland calcareous Grassland; Lowland Calcareous Grassland; Hedgerows. For rarer habitats, insufficient area within GMEP 1km squares may rule out useful estimation of extent however in those areas surveyed, fixed vegetation plots will be recorded since all mapped areas of Priority Habitat are sampled by default. While it may be possible to derive and report condition for these areas based on coincident plots the question arises as to how representative the vegetation plot sample might be of the total extent. Thus reporting of these condition measures will need to be accompanied by a characterisation of the resource they represent, for example in terms of geographical location, patch size and other spatial or ecological biases.

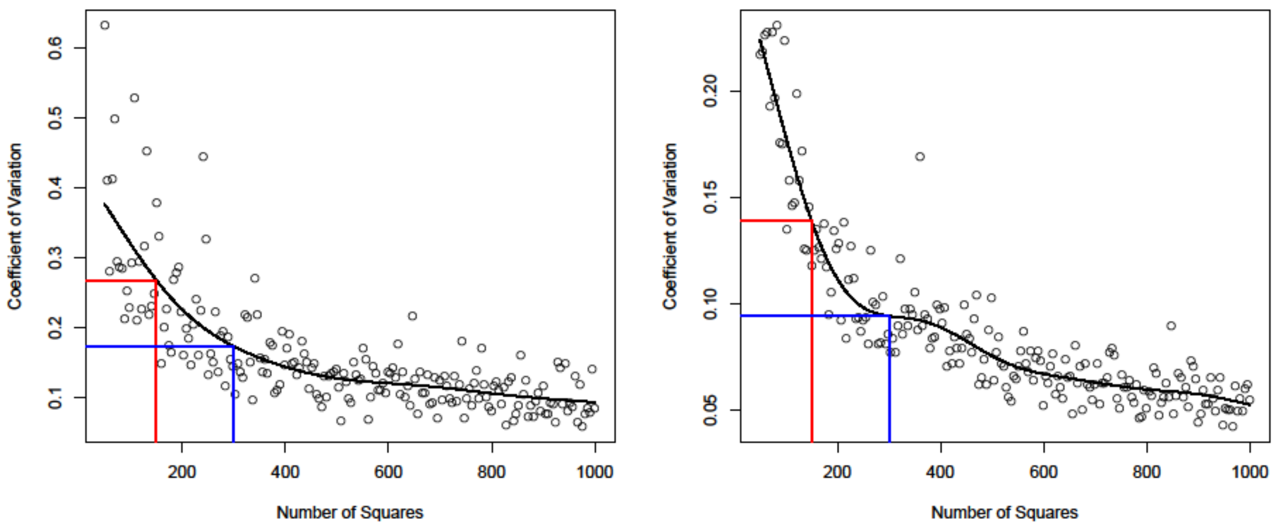


Figure 5.2.4.4.1 a (left) & b (right) *Estimating uncertainties for national estimates of extent based on the GMEP sample of 1km squares for a hypothetical habitat assumed to cover 2000 (a) or 20000ha (b) of Wales. Points are the CV values that arise from a random distribution of areas of habitat among different numbers of GMEP 1km survey squares assuming different national extents of each habitat.*

5.2.3 Distribution of Section 42 species and their coincidence with GMEP 1km survey squares

Work in years 2 and 3 has focussed on gathering up-to-date distribution data for Section 42 species that are associated with their own bundles of specific options within the Glastir scheme. These data are required at 1km resolution to determine whether recently recorded populations coincide with GMEP 1km survey squares where associated Glastir options have been taken up (see Section 5.2.2). Coincidence is reported for the analyses of habitat indicator variables for a range of Section 42 species covering Dormouse, rare arable plants, Lapwing, Lesser Horseshoe Bat, Curlew and Marsh Fritillary Butterfly (see section 5.3.3 and Appendix 5.10). Because GMEP includes butterfly and bird surveys, Section 42 species in these groups have been recorded where possible in GMEP 1km survey squares. These records are reported below for years 1 and 2. Other taxa are not recorded in GMEP and so we rely on records from other schemes and recorders to fill the gap. The Biological Records Centre at CEH Wallingford issued a request to data providers for updated distributional data at 1km square resolution. In addition the Bat Conservation Trust and Plantlife kindly provided recent records for Section 42 bats, lichens, plants and fungi (Table 5.2.3.1). The coincidence between these recently acquired 1km square records and GMEP 1km survey squares is shown in Table 5.2.3.2. These numbers should increase once year 3 and 4 GMEP 1km survey squares are included.
The numbers of post-1970 records coinciding with year 1 and 2 GMEP 1km survey squares are low (Table 5.2.3.2). This is not surprising given the rarity of the species concerned. Our approach to exploring the potential effect of Glastir is therefore to measure the impact of Glastir options associated with each rare species on ecological conditions in all locations, including those where the rare species has not been recently recorded in GMEP 1km survey squares. Thus the question of whether options can successfully drive ecological changes that would be expected to favour each species is treated separately from whether option-induced ecological change spatially coincides with rare species populations. However, if the number of coincidences between species records and option uptake is large enough then it will be possible to examine Glastir effects in these situations thus providing a more direct test of the relevance of options to the target species. Accumulating as much distributional data as possible for each species is therefore important. Whilst efforts have been made to accumulate recent records at 1km resolution, gaps in coverage remain. Mammals in particular require further effort. For example, the number of Dormouse records visible on the NBN portal greatly exceeds the number acquired by BRC at 1km resolution because data owners were reluctant to allow access to these data. Ongoing work will further engage the recording community including Welsh Local Record Centres. We will attempt to provide the assurances needed to secure access to greater numbers of records. BTO surveyors also record mammal sightings in GMEP 1km survey squares and these data will also be added to the 1km observational database as they accumulate.

S42 Species	Data Resolution	Received from	Year	Organisation	Total number of 1km records
Arable plants	1km-100m	Trevor Dines	post-1987	Plantlife	79
Artic-Alpine plants	1km-100m	Trevor Dines	post-1987	Plantlife	44
Heathland plants	1km-100m	Trevor Dines	post-1987	Plantlife	146
Lichens of waysides and parkland trees	1km-100m	Trevor Dines	post-1987	Plantlife	301
Metal-mine lichens	1km-100m	Trevor Dines	post-1987	Plantlife	5
Fungi	1km-100m	Trevor Dines	post-1987	Plantlife	214
Barbastelle Bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	8
Bechstein's Bat	No distribution data available from BRC or BCT				
Lesser horseshoe Bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	659
Great horseshoe bat	1km 10km 1 & 10km	Bjorn Beckmann Bjorn Beckmann Kate Barlow	post-1970 post-1970 post-1970	BRC/CEH BRC/CEH BCT	149
Dormouse	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	66
Great Crested Newt	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	297
Red Squirrel	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	70
Water Vole	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	54
Brown-Banded Carder Bee	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	8
Shrill Carder Bee	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	6
High Brown Fritillary	1km	Bjorn Beckmann	post-1970	BRC/CEH	42
Marsh Fritillary	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	606
Pearl Bordered Fritillary	1km 10km	Bjorn Beckmann	post-1970 post-1970	BRC/CEH	176
Welsh Clearwing	1km	Bjorn Beckmann	post-1970	BRC/CEH	103

Table 5.2.3.1 *Number of 1km square records for Section 42 species that have dedicated bundles of Glastir options. Bird distribution data is covered separately in 5.3.2.3.* ***Abbreviations:*** *CEH – Centre for Ecology and Hydrology; BCT – Bat Conservation Trust; BRC – Biological Records Centre.* ***Notes:*** *Complete data sets for all S42 species were not received due to organisations not providing permission to share third party data sets. This issue alone is the reason why no Bechstein's bat data could be provided for analysis. The incompleteness of the distribution data is particularly visible on*

the NBN interactive map. For example, only 66 1km dormouse records were received by BRC, yet the NBN gateway holds a total of 358 dormouse records at 1kmresolution within Wales.

Section 42 species associated with Glastir options	Number of post-1970 records that coincide with yr 1 & 2 GMEP 1km survey squares
Lesser Horseshoe Bat	**14**
Greater Horseshoe Bat	**2**
Barbastelle Bat	**1**
Hazel Dormouse	**0**
Water Vole	**2**
Red squirrel	**1**
Great Crested Newt	**2**
Arable plants	**0**
Arctic-Alpine plants	**0**
Grassland plants	**0**
Heath plants	**1**
Lichens of wayside and parkland trees	**5**
Metal-mine lichens	**0**
Grassland fungi	**1**
Brown-Banded Carder Bee	**0**
Shrill Carder Bee	**0**
High Brown Fritillary	**1**
Marsh Fritillary	**13**
Pearl Bordered Fritillary	**5**
Welsh Clearwing	**2**

Table 5.2.3.2 *Coincidence between post-1970 records for Section 42 species associated with Glastir options and surveyed GMEP 1km survey squares from 2013 and 2014. Bird distribution data and coincidence are covered separately in section 5.3.*

5.2.4 Occurrence of Section 42 species directly reported by the GMEP field surveyors

Species of principal importance in Wales listed under Section 42 of the NERC Act, are a key policy priority. It is therefore of interest to determine which of these species could potentially be monitored under GMEP and which will require additional survey effort, either via independent surveys or via specific targeting through the Targeted element of GMEP. Since the field survey component includes butterfly and bird surveys and census of vegetation plots there is potential for encountering Section 42 taxa in these groups. Results for the year 1 and 2 surveys are shown below. Other Section 42 taxa are not directly measured in GMEP. They require other methods particularly with regard to detecting impacts of Glastir options. Our approach to this problem is two-fold: current distribution data is used to determine whether a target species coincides with GMEP 1km survey squares in which options linked to the species have been taken up. Then, irrespective of the distribution of the target species, we separately quantify indicators of change in ecological conditions associated with the expected impact of the species-specific Glastir options. See section 5.3.3 and Appendix 5.10.

5.2.4.1 Plants

No Section 42 plant species were recorded in year 1 and 2 vegetation plots.

5.2.4.2 Butterflies

Of the 15 Section 42 butterflies 7 have been recorded in GMEP 1km survey squares in years 1 or 2. Pearl-bordered and Marsh Fritillary have not yet been recorded in GMEP. Of the 3 species specifically targeted by Glastir only High Brown Fritillary has so far been recorded (Table 5.2.4.2.1).

SPECIES	**No. GMEP 1km survey squares 2013-14**	**% GMEP s1km survey squares 2013-14**
Brown Hairstreak	1	1
White-letter Hairstreak	2	1
Small Pearl-bordered Fritillary	6	4
High Brown Fritillary	1	1
Wall Brown	24	16
Grayling	3	2
Large Heath	2	1

Table 5.2.4.2.1 *Non-zero counts of Section 42 butterflies in GMEP 1km survey squares from the year 1 and 2. The remaining eight Section 42 species have not yet been recorded.*

5.2.4.3 Birds

The GMEP field surveys are designed to cover a representative sample of the common and widespread habitats found in Wales, with the addition of a targeted sample considering priority habitats or forms of management. To date, the sample has not been targeted towards birds of conservation concern, but such species are nevertheless of interest for monitoring. Specifically, the species of principal importance in Wales listed under Section 42 of the NERC Act. 504 are a key policy priority. It is therefore of interest to determine which of these species could potentially be monitored under GMEP and which will require additional survey effort, either via independent surveys or via specific targeting through the Targeted element of GMEP.

The bird survey results from the GMEP field surveys were summarized to reveal GMEP 1km survey squares where the bird species that have been identified as Section 42 priorities (http://www.eryri-npa.gov.uk/__data/assets/pdf_file/0003/486156/SpeciesList.pdf) were recorded in 2013 and 2014.

Species name	Number of GMEP 1 km survey squares		Notes
	2013	2014	
Aquatic Warbler	0	0	Globally endangered, not in Wales
Bar-tailed Godwit	0	0	Winter - WeBS
Common Bullfinch	27	31	
Black-headed Gull	2	6	Colonial - will always be in a small number of locations; monitored by WeBS
Great Bittern	0	0	Extinct?
Black Grouse	0	0	Surveyed regularly by RSPB
Tundra Swan	0	1	Winter - monitored by WeBS
Corn Bunting	0	0	Extinct
Corn Crake	0	0	Extinct
Chough	5	3	Surveyed annually independently
Common Cuckoo	13	12	
Eurasian Curlew	6	13	
Common Scoter	0	0	Winter - monitored by WeBS
Dunnock	48	61	
Dark-bellied Brent Goose	0	0	Winter - monitored by WeBS
Red-backed Shrike	0	0	Extinct
Grasshopper Warbler	9	9	
Golden Plover	1	0	Surveyed periodically by RSPB
Hawfinch	1	0	
Herring Gull	11	24	monitored by WeBS
Hen Harrier	1	3	Surveyed periodically independently
House Sparrow	33	43	
Kestrel	5	5	
Northern Lapwing	6	5	
Common Linnet	32	35	
Lesser Redpoll	19	26	
Lesser Spotted Woodpecker	0	0	Now very rare
Marsh Tit	10	3	
European Nightjar	0	0	Nocturnal
Greenland Greater White-fronted Goose	0	0	Winter - monitored by WeBS
Grey Partridge	2	1	
Pied Flycatcher	8	4	
Reed Bunting	16	25	
Red Grouse	1	4	
Ringed Plover	0	2	Monitored by WeBS
Ring Ouzel	2	1	
Roseate Tern	0	0	Very rare
Sky Lark	31	38	
Spotted Flycatcher	15	4	

Common Starling	15	23	
Song Thrush	42	58	
European Turtle Dove	0	1	Now very rare
Tree Pipit	13	12	
Eurasian Tree Sparrow	0	1	Now very rare
Twite	1	0	Surveyed regularly by RSPB
Wood Lark	0	0	Extinct
Wood Warbler	7	1	
Willow Tit	5	0	
Yellowhammer	10	9	
Yellow Wagtail	1	1	Rare in Wales, only near English border

Table 5.2.4.3.1 *Coverage of Section 42 bird species by GMEP field surveys. Species that are now extinct in Wales are identified, as are wintering and breeding wetland or coastal species that are monitored by the Wetland Bird Survey (WeBS).*

The numbers of GMEP 1km survey squares where each Section 42 species was recorded in the GMEP 1km survey squares are listed in Table 5.2.4.3.1. This indicates that there is good potential to monitor change, or to investigate habitat relationships such as the selection or otherwise of Glastir option habitat, in many of these species. Exceptions include those that now extinct as breeding species in Wales, one nocturnal (or crepuscular) species and those that are only winter visitors. Nocturnal species require bespoke monitoring, but wintering wetland species, especially those found in coastal locations, are well monitored by the BTO/JNCC/WWT Wetland Bird Survey (WeBS), which provides monthly data on near-complete counts of UK wintering waterfowl and wader populations each year. It also provides data on breeding populations for those waterbirds that also breed in Wales; these data may be more useful than any available BBS counts for species that are mostly found on larger water bodies. Summary data on these populations are freely available and patterns of population change have been summarized within GMEP reporting with reference to long-term trends (Appendix 5.3). This leaves around 14 species which do not fall into these categories and had counts of 10 or more in 2 years of the baseline survey with another 2 years of baseline still to come.

Nevertheless, some species are too rare to be monitored under GMEP without specific targeting and, perhaps, bespoke survey methods. Their coverage therefore reflects the targeting strategy behind GMEP sampling set by the Welsh Government, but it is important to note that specific surveys for a wide range of ecologically different and geographically separated species will always be difficult to manage logistically in the context of limited resources. Changes in very rare species are reported independently via periodic atlas projects, such as the recent Bird Atlas 2007-11 (Balmer et al. 2013), while some species are subject to formal or informal monitoring by independent observers. GMEP will endeavour to collate data from such sources to inform about long-term population trends (see Section 5.2.1.3) and, for well-monitored species, analyses specifically investigating the effects of Glastir management may be possible. Chough is one species for which the latter should be feasible.

5.2.5 What are the long term trends in Habitat diversity?

5.2.5.1 Background

Habitat diversity can be a good thing in that a mixture of habitats provides variety in abiotic conditions, food and shelter and is preferable to a species-poor monoculture. High habitat diversity should provide resilience from changing environmental conditions (e.g. climate change) enabling species to move between habitats when conditions change. However, high habitat diversity can also be a sign of increasing fragmentation and it is important that larger continuous areas of habitat are also maintained for example, in unenclosed upland environments. Habitat diversity and connectivity (reported elsewhere) can both contribute to the creation of ecological networks which have an important role to play in the conservation of habitats and species in an increasingly fragmented landscape.

5.2.5.2 Methods

Habitat diversity and the mean area of a habitat patch within a 1km square have been calculated from field survey data. All Habitats are mapped within a 1km square to Broad and Priority habitat classification by surveyors in the field using a computer with bespoke GIS technology. This classification has been applied continuously from 1984 to 2014. The Shannon diversity index (H´) following the formula - $\Sigma\, p_i \ln p_{i,}$ was used to calculate habitat diversity where $p_{i,}$ is the proportion of habitat $_{i.}$. Habitats were substituted for species and 1km squares for quadrats. Urban areas were excluded and all Priority Habitat types were included as separate habitats. The mean patch size was calculated from the area data as a mean per 1km square.

5.2.5.3 Results

There has been no significant change in habitat diversity between 1984 and 2014.
Although Figure 5.2.5.3.2 does suggest an increasing trend in mean patch size there has been no significant change in mean patch size between 1984 and 2014.

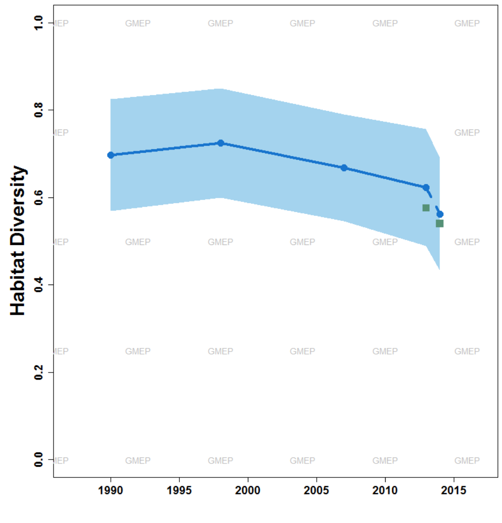


Figure 5.2.5.31: *Trends in habitat diversity (Shannon diversity index) between 1984 and 2014*

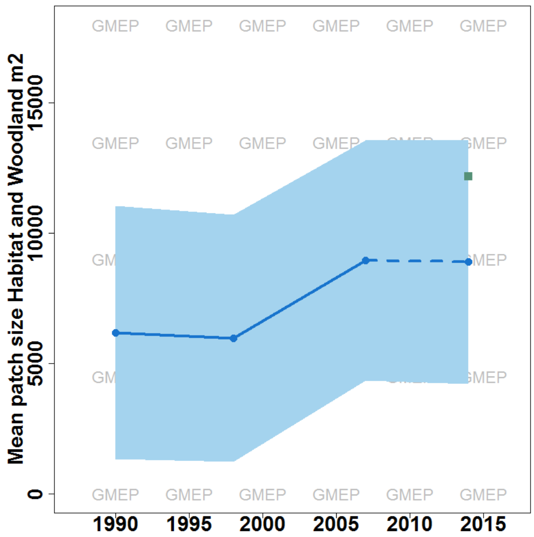


Figure 5.2.5.3.2: *Trends in mean habitat patch size ('habitat' land and woodland) between 1984 and 2014*

Table 5.2.5.3.1: *Mean Habitat Diversity over Time.*

Year	Estimated_Value	Lower_est.	Upper_est.
1990	0.70	0.58	0.82
1998	0.73	0.61	0.84
2007	0.67	0.55	0.78
2013 GMEP	0.62	0.47	0.70
2014 GMEP	0.56	0.43	0.69

There are no significant differences between years

Table 5.2.5.3.2: *Changes in mean patch size over time*

Year	Estimated_Value	Lower_est.	Upper_est.
1984	6190.023	1330.801	11049.24
1990	5983.114	1240.993	10725.23
1998	8960.202	4349.773	13570.63
2007	8913.32	4219.516	13607.12
2013/14 GMEP	6190.023	1330.801	11049.24

There are no significant differences between years

5.3 Glastir impacts on Section 42 bird species

One of the six objectives of Glastir is to "conserve and enhance wildlife and biodiversity", a goal that is inherited from the preceding Tir Gofal (TG) scheme. Quantifying the role of Glastir in conserving and enhancing wildlife and biodiversity requires measuring the impacts of options on Section 42 species. While our starting point is the GMEP survey that began in 2013, our expectations about the impact of Glastir and interpretation of future analyses of ecological change should take into account how previous schemes may already have shaped the baseline that we characterize during the first 4 years of survey. There are three aspects to this;

1) Reviewing evidence of the impacts of previous schemes based on monitoring across Wales;
2) Quantifying the legacy effects of these schemes by answering the question 'can we detect the influence of previous scheme impacts within GMEP survey data?' Answering this question is restricted at this stage to just survey data for years 1 and 2;
3) Investigating whether legacy effects are detectable in other recording schemes.

We present new evidence on all three fronts. Below we briefly review the evidence from previous monitoring of AES impacts on biodiversity in Wales. Then we summarize two new analyses that seek to detect legacy effects of previous Welsh schemes. The first is an analysis of the impacts of Tir Cynnal and Tir Gofal on bird species across the 1km squares visited as part of the Breeding Bird Survey in Wales. The second analysis is a preliminary attempt to detect differences in plant species compositional indicators in year 1 and 2 GMEP vegetation plots between those that were managed under habitat-specific Tir Gofal options versus plots never in agreement land but referable to the same habitat types.

5.3.1 Evidence for previous AES impacts in Wales; a summary of the Tir Cynnal and Tir Gofal monitoring and evaluation programme

The Tir Cynnal and Tir Gofal monitoring and evaluation was split into three components; habitats, species and soil, carbon and water. The results for habitats (Medcalf et al. 2012) and species (McDonald et al. 2012) are relevant to biodiversity and are summarized below.

5.3.1.1 Habitats

- Tir Cynnal habitat monitoring occurred over a three year period, with a baseline established in the first year.
- Remote sensing was used to assess habitat distribution
- Tir Gofal habitats were monitored for 11 years with a baseline survey and two re-surveys after 6-8 and 9-11 years.
- Importantly, success of habitat prescriptions was evaluated against performance indicators which were set for each habitat. These generally looked at vegetation characteristics which were thought to be indicators of habitat condition. This is the most similar approach to that being applied in GMEP. The indicators were then evaluated against a set of conditions to identify whether the habitat had undergone positive ecological change
- Key results for Tir Cynnal:
    - Generally evaluated as successful at habitat protection
    - Habitat loss was greater in farms out of the scheme, indicating the scheme was reducing habitat loss.
- Key results for Tir Gofal:
    - Grassland reversion had generally been successful. Species-rich grassland and grazed coastal grassland had been successfully maintained and enhanced
    - Tir Gofal had been successful in maintaining other habitats included woodland and parkland, blanket bog and marshy grassland
    - Tir Gofal was not successful in enhancing fen and flush habitats
    - Heathland was being maintained where present but heathland reversion was generally not successful.

5.3.1.2 Species

- Monitoring of both Tir Cynnal and Tir Gofal occurred between 2009 and 2012 with most effort was spent on assessing Tir Gofal impacts
- Monitoring focused on specific taxa of plants, fungi, bats, butterflies, birds and mammals chosen based on conservation importance and because their expected responses to AES were known.
- No baseline data were available so comparisons were made with non-AES farms and between fields in option and out of option. Therefore it is not possible to distinguish between TG effects and initial condition
- Overall relatively few taxa showed differences between in and out-of-option land.
- Key findings are summarized below, grouped by target species

Taxon group	Indicators used	Options with evidence of benefit	Options with no benefit/other issues
Bats	Activity	Soprano pipistrelle activity higher with unimproved neutral grass (8B), hedgerow restoration (TG18) and broadleaf woodland stock excluded (1A).	No difference in activity between TG farms and non-AES farms.
Birds	Abundance, territory occupancy, hatching, productivity	Yellowhammer positively linked to Tir Gofal in general. Lapwings positively associated with option 34A (manage Improved Grassland for lapwing). Chough preferentially foraged in fields under TG options in winter	Black grouse lek counts not linked to AES

Arable plants and grassland fungi	Diversity	Increased diversity under 24A (unsprayed fields) and 29 (fallow margins). Fallow margins had a greater diversity of plants providing overwinter seed resources	No effect of TG on crystalworts, hornworts or liverworts No evidence of TG effects on grassland fungi.
Butterflies	Occupancy, abundance, habitat quality	Some evidence of improved habitat quality on TG farms for brown hairstreak and marsh fritillary. Heathland (5 and 6) had higher small pearl-bordered fritillary occupancy and brown hairstreak was more abundant in semi-improved (10) fields cf. improved	No evidence of improvement for three species (small pearl-bordered fritillary, marsh fritillary and brown hairstreak) No changes in abundance for any target species Prescriptions may not be specific or restrictive enough to affect butterflies
Mammals	Population size, abundance, occupancy	Brown hare populations were greater on TG farms	No effect of TG on water voles, occurrence maybe related to habitat characteristics not affected by TG or predation

Table 5.3.1.2.1 *Summary of evidence for the effects of Tir Gofal (TG) scheme options on species groups (from McDonald et al. 2012).*

5.3.2 Legacy effects of agri-environment schemes on birds in Wales

5.3.2.1 Introduction

Birds are a key component of biodiversity, both for their own, intrinsic, conservation interest and as indicators of the broader health of the environment, as is reflected in the policy targets that involve bird populations. Agri-environment schemes (AES), including Glastir and its predecessors, typically include multiple management options aimed wholly or partly at benefiting birds, including conservation-priority species. It is critical to monitor AES to ensure that public funds are being spent effectively and the successes and failures of legacy schemes are important in that they inform the ongoing development of ongoing and future management, such as is found under Glastir.
Previous studies have successfully tested the impacts of English AES on birds using national-scale survey data (e.g. Baker et al. 2012), so the same approach has been applied to Wales, measuring the effects of all management options that might benefit birds on all relevant individual species for which sufficient data were available. A full description of the methods and results of this part of the GMEP project is available in Appendix 5.1, but the key points are summarized here.

5.3.2.2 Methods

The BBS is a volunteer survey conducted annually in a random sample of 1km squares across Wales using standardized methods. Counts of individual species from each square were analysed using an established method to estimate population growth rates and the effects thereon of quantities of AES options in the survey squares each year. The AES data were option areas and lengths, combined with maps of the boundaries of individual Tir Gofal (TG) and Tir Cynnal (TC) agreements. Rather than an in-scheme/out-scheme comparison, the analyses compared bird population changes between squares with different quantities of management.

Following studies done on Environmental Stewardship in England (Baker et al. 2012), TC and TG effects were assessed for individual species-option combinations, using data from two years before each scheme began to the present day. Population growth rates (changes from year to year) were analysed to reveal variation with different quantities of relevant AES management in and around BTO/JNCC/RSPB Breeding Bird Survey (BBS) 1km squares. Analyses used generalized linear models and controlled for potentially confounded habitat factors. Data on management under TC (2005-2013) were not available, so proxies had to be used (amounts of different land cover types overlapping TC agreement). TG management (1999-2013) was tested considering groups of options providing Grassland habitat, Arable winter seed, Arable invertebrates, Woodland creation & stock exclusion, Heathland, Scrub management and hedgerow management.

5.3.2.3 Results

The analyses of proxies for TC management failed to produce clear results, but analyses of TG data were more successful. Positive associations with TG options were much more common than negative ones, particularly for woodland and hedgerow management, followed by arable seed provision and scrub management (Figure 5.3.2.3.1).

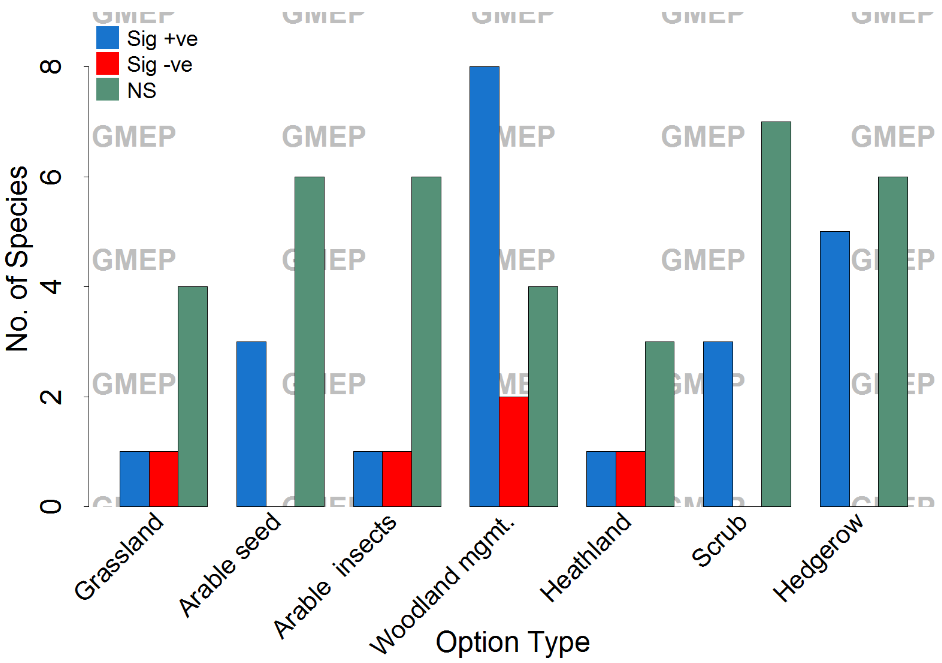


Figure 5.3.2.3.1 *Numbers of species with positive, negative and non-significant associations with TG option groups.*

Table 5.3.2.3.1 shows the results in more detail, by species. The balance of positive versus negative patterns, given that 5% of the results would be expected to be “significant” by chance and that the power to detect effects of many option types is likely to have been low because sample sizes of both AES management and areas of some land-uses (e.g. arable) were small, is informative. The evidence therefore supports broadly positive effects of TG, notably involving management of woodland, scrub, hedgerows and habitats providing winter seed in arable farmland.

Option type	Species tested	Significant effects	
		Positive	Negative
Grassland management	CU, L, LI, MP, S, SG	LI	S
Arable winter seed	CH, D, GR, HS, LI, RB, SD, S, Y	Y, GR, SD	
Arable invertebrates	CH, D, HS, RB, S, SG, WH, Y	WH	HS
Woodland creation & stock exclusion	B, BC, BT, CC, CH, GT, PF, R, RT, SF, ST, WO, WR, WW	B, BC, CC, R, SF, ST, WO, WR	BT, R
Heathland	CU, MP, S, SC, L	S	L
Scrub management	BC, CC, D, LI, R, SC, WH, WR, WW, Y	CC, WR, WW	
Hedgerow management	BF, CH, D, GO, GR, HS, LI, RB, SD, ST, WH	D, ST, LI, HS, GR	

Table 5.3.2.3.1 *Details of bird species for which the effects of each TG option type were tested and for which the results were significantly positive or negative.*

5.3.2.4 Discussion

The benefits of TG for birds identified here probably reflect effects on resources used by birds, including physical habitat structure and other biodiversity. There are, therefore, likely to be co-benefits to those other elements of the environment. However, many co-benefits are likely to involve resource quantities (e.g. prey biomass), rather than, necessarily, the occurrence of priority species. Note also that birds will respond to the alleviation of their limiting factors, so bird changes will reflect those in other groups (and vice versa) only if the latter are directly or indirectly associated with those limiting factors.

Weaknesses with this study include the inability to assess rarer species and options because of small sample sizes, so the results may not reflect high conservation priorities. The balance of effects across species for several option types suggests that TG has been broadly beneficial; for other options, either small sample size effects (e.g. heathland) or failure to address limiting factors (e.g. arable invertebrate options) probably underlie the limited effects.

The failure of the study to provide convincing tests of TC management effects was disappointing, but probably reflects the lack of good data for the types and quantities of management undertaken. If data on this scheme existed, they appear now to have been lost. However, should such data be found (i.e. spatially explicit information on areas of types of “wildlife habitat” created or protected under TC and the natures of each of those habitat patches), it would be valuable (and straightforward) to repeat the analyses described above.

BBS code	**English name**	**Scientific name**	**BBS code**	**English name**	**Scientific name**
B.	Blackbird	*Turdus merula*	P.	Grey Partridge	*Perdix perdix*
BC	Blackcap	*Sylvia atricapilla*	PF	Pied Flycatcher	*Ficedula hypoleuca*
BO	Barn Owl	*Tyto alba*	R.	Robin	*Erithacus rubecula*
BK	Black Grouse	*Tetrao tetrix*	RB	Reed Bunting	*Emberiza schoeniclus*
BT	Blue Tit	*Cyanistes caeruleus*	RG	Red Grouse	*Lagopus lagopus*
BZ	Buzzard	*Buteo buteo*	RK	Redshank	*Tringa totanus*
CB	Corn Bunting	*Emberiza calandra*	RT	Redstart	Phoenicurus phoenicurus
CC	Chiffchaff	*Phylloscopus collybita*	RZ	Ring Ouzel	*Turdus torquatus*

CF	Chough	*Pyrrhocorax Pyrrhocorax*	S.	Skylark	*Alauda arvensis*
CH	Chaffinch	*Fringilla coelebs*	SC	Stonechat	Saxicola rubicola
CU	Curlew	*Numenius arquata*	SD	Stock Dove	*Columba oenas*
D.	Dunnock	*Prunella modularis*	SE	Short-eared Owl	*Asio flammeus*
DN	Dunlin	*Calidris alpina*	SF	Spotted Flycatcher	*Muscicapa striata*
DW	Dartford Warbler	*Sylvia undata*	SG	Starling	*Sturnus vulgaris*
GO	Goldfinch	*Carduelis carduelis*	SH	Sparrowhawk	*Accipiter nisus*
GR	Greenfinch	*Chloris chloris*	SN	Snipe	*Gallinago europeo*
GL	Grey Wagtail	*Motacilla cinerea*	ST	Song Thrush	*Turdus philomelos*
GP	Golden Plover	*Pluvialis apricaria*	TS	Tree Sparrow	*Passer montanus*
GS	Great-Spotted Woodpecker	*Dendrocopos major*	W.	Wheatear	*Oenanthe oenanthe*
HH	Hen Harrier	*Circus cyaneus*	WC	Whinchat	*Saxicola rubetra*
HS	House Sparrow	*Passer domesticus*	WH	Whitethroat	*Sylvia communis*
K.	Kestrel	*Falco tinnunculus*	WO	Wood Warbler	*Phylloscopus sibilatrix*
KF	Kingfisher	*Alcedo atthis*	WP	Woodpigeon	*Columba palumbus*
L.	Lapwing	*Vanellus vanellus*	WR	Wren	*Troglodytes troglodytes*
LI	Linnet	*Carduelis cannabina*	WT	Willow Tit	*Poecile montana*
ML	Merlin	*Falco columbarius*	WW	Willow Warbler	*Phylloscopus trochilus*
MP	Meadow Pipit	*Anthus pratensis*	Y.	Yellowhammer	*Emberiza citrinella*
MR	Marsh Harrier	*Circus aeruginosus*			
MT	Marsh Tit	*Poecile palustris*			
OC	Oystercatcher	*Haematopus ostralegus*			

Table 5.3.2.4.1 *Key to BBS species codes: English and scientific names.*

5.3.3 Preliminary analysis of GMEP vegetation plots: can we detect a legacy effect of Tir Gofal on baseline habitat condition?

5.3.3.1 Introduction

A complete account of this analysis is in Appendix 5.2. To investigate and quantify legacy effects we analysed differences in vegetation between plots that were on land that had previously been under the Tir Gofal scheme and plots that had never been under Tir Gofal. Tir Gofal was a higher level agri-environment scheme with a focus on enhancing existing habitats. The scheme ran from 1999 to 2012 and had components for both maintenance of existing habitats (“maintain” options) and for conversion or extensification of improved land (“enhance” options) (Medcalf *et al*. 2012). The evidence for a legacy effect on current performance indicators as a result of previous Tir Gofal prescriptions was evaluated from vegetation plot data from the Year 1 and 2 GMEP surveys. Increased statistical power will arise when Years 3 and 4 of the first GMEP roll are included and so the results of this analysis should be considered preliminary.

5.3.3.2 Methods

Coincidence between GMEP survey plots and land previously under Tir Gofal was assessed using spatial data provided by the Welsh Government for the extent of Tir Gofal options. This information was resolved at the parcel and linear feature level so that coincidence between plots and locations could be established with a high level of precision. Initial investigation showed that 1,043 out of 4,135 (25%) of year 1 and 2 GMEP plots were in land that had previously been under a Tir Gofal option. Of these, most had been under options to maintain unenclosed grassland, wet grasslands, raised and blanket bog. The nine options present in more than 40 GMEP 1km survey squares were investigated further.

For each option, or combination of options, differences in a number of habitat condition indicators were evaluated between plots on land that had been under the relevant Tir Gofal option and plots on land where the option had never been applied. Each Tir Gofal option only applies to a certain number of habitats, for example marshy grassland maintenance option (11) only applies to habitat already containing marshy grassland (Broad Habitat classification fen, marsh and swamp). Therefore, when comparing plots in land that had been in Tir Gofal to land never in Tir Gofal, it is important to only use comparable habitat types. For example, to look at the effect of option 11 on maintaining marshy grassland only plots in fen, marsh and swamp that had never been under Tir Gofal option 11 would be used as the counterfactual. The same process was used to determine counterfactual datasets for other options: the habitat and landscape location (area of habitat or linear feature) impacted by the option were used as criteria to select equivalent plots sampling the same kind of habitat and feature but never subject to Tir Gofal options according to the spatial data layers provided.

The Tir Gofal scheme ran between 1999 and 2012, with new entrants only accepted until 2009. Plots that entered in the first half of the scheme (1999 to 2006) had therefore been under options for longer, and might be expected to show more change, than plots which only entered in the latter half of the scheme (2006-2012). To account for this, differences were investigated between three groups of plots: Never in Tir Gofal, Entered Tir Gofal post-2006 and Entered Tir Gofal pre-2006. Differences in performance indicators between these groups were assessed using linear mixed models where Tir Gofal group (Never in Tir Gofal, entered post-2006, entered pre-2006) was a fixed effect and survey square was a random effect. Where the indicator was a count variable (e.g. total richness) generalised linear mixed models with a Poisson distribution were used. The expectation was for greater differences to be present between counterfactual plots and Tir Gofal plots that had entered earlier rather than later. Without more intensive time series monitoring it is not possible to say however whether such effects are evidence of a positive change over time or better targeting of habitat that entered the scheme earlier.

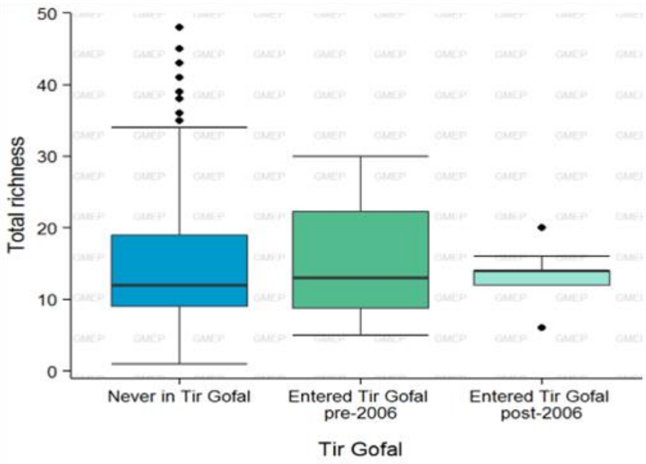
5.3.3.3 Results

For the vast majority of indicators (42 out of 45) there was no evidence that plots occurring on land previously subjected to Tir Gofal prescriptions had different values to plots on land which had never been under Tir Gofal (see Appendix 5.2). In three cases a significant difference was observed between the Tir Gofal groups (Table 5.3.3.3.1). For one of these cases, a difference in bracken cover under options 7A and 7B, there was very little data available and therefore the confidence in this result is low. For the other cases where a significant difference was seen, one (total species richness under option 1A) only showed significant differences between the two time periods of Tir Gofal application and no difference from land where Tir Gofal was never applied. This is due to the larger variation in richness in land where Tir Gofal never occurred, even after filtering for habitat and plot type (Figure 5.3.3.3.1 a). For option 1A (Ungrazed broadleaved woodland) species richness was higher in plots that had entered Tir Gofal before 2006. In one case there were significant differences between plots in land that had entered Tir Gofal before 2006 and plots that had never been under Tir Gofal. Plots that had entered option 5 (maintain upland heath) before 2006 had lower grass:forb ratio in 2013/14 than plots never in Tir Gofal (Figure 5.3.3.3.1 b).

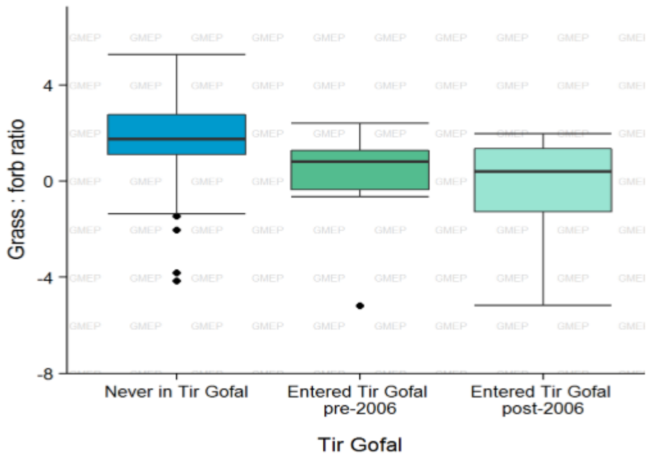
Option	Indicator	Comparison	Estimated difference	P value
1A	Total species richness	Entered Tir Gofal post-2006 - Entered Tir Gofal pre-2006	-0.39215	0.0272
5	Grass:forb ratio	Entered Tir Gofal pre-2006 - Never in Tir Gofal	-1.82549	0.0077
7A/7B	Bracken cover	Entered Tir Gofal pre-2006 - Never in Tir Gofal	1.544481	0.0425†

† There was very little data to support this result so it is not discussed further.

Table 5.3.3.3.1 Tests *of the difference between each indicator variable in groups of plots that came into Tir Gofal earlier (pre-2006) or later (post-2006) versus counterfactual plots never in Tir Gofal but in equivalent habitat type.*



Option 1a



Option 5

Figure 5.3.3.3.1 *Significant differences in indicator variables between plots in land that entered Tir Gofal in two different time periods (before or after 2006) and plots that had never been in Tir Gofal. Corresponding significance tests are presented in Table 5.3.3.3.1 and total numbers of plots in each analysis in Table 5.3.3.3.2*

Option code	Number of plots in option	Number of plots in counterfactual
11	28	183
18	33	534
1A	21	221
40A	28	170
5	19	217
7A/7B	55	143
7B/12	38	156

Table 5.3.3.3.2 *Number of GMEP vegetation plots from the year 1 and 2 surveys that coincided with Tir Gofal options and counterfactual plots never in Tir Gofal.*

5.3.3.3.4 Discussion

In interpreting the impacts of legacy schemes on the baseline conditions observed in GMEP 1km survey squares it is important to note that the GMEP survey was not designed to evaluate legacy scheme effects and therefore our results may differ from the monitoring conducted by past agri-environment schemes. In particular, we only attempted to detect the signal of Tir Gofal in the first two years of GMEP survey data. Our sample sizes were therefore small compared to previous more intensive evaluation of Tir Gofal in which a wider range of scheme effects were detected (Medcalf et al. 2012). In addition, we have only evaluated one past scheme and our sample size is small for most Tir Gofal options, therefore caution should be used in evaluating the results. However, despite these concerns, it is important to consider the potential effects of previous agri-environment schemes on the baseline conditions recorded by the GMEP survey. If there was evidence that Tir Gofal was responsible for differences in the baseline levels of indicators recorded then it would be important to account for this effect in future analyses of Glastir impact to avoid incorrectly attributing change. Our analysis suggests that, within the first and second years of GMEP recording, there was little evidence that Tir Gofal had led to lasting changes in the indicators measured. Only three out of 45 option-indicator combinations showed any influence of Tir Gofal occurrence or duration and only two of these showed differences between plots that had been in Tir Gofal and those that had not which were well supported by the data (i.e. excluding the difference in bracken cover in option 7A/7B).

Grass:forb ratio was found to be significantly lower in upland heathlands that had been maintained under Tir Gofal option 5 than in heathlands that had never been in Tir Gofal. Low grass:forb ratio is considered to be indicative of better ecological condition, as a high proportion of graminoids is often a result of excessive nutrient enrichment or over-grazing. Unfortunately, grass:forb ratio was not used as a performance indicator in the Tir Gofal monitoring surveys and therefore a direct comparison with this evaluation cannot be made. However, the Tir Gofal monitoring report (Medcalf et al. 2012) did conclude that heathland sites were generally being well protected by Tir Gofal, with 45% of sites improving in ecological condition. The report also concluded that changes in condition in heathland were likely to occur in the long term as most changes were observed in only the second of two resurveys, eight years after the start of Tir Gofal. Our results support this conclusion, with only plots that entered Tir Gofal before 2006 having a significantly lower grass:forb ratio.

Overall our results suggest that, in most cases, there is no evidence that Tir Gofal has led to long term changes in the indicators assessed which would need to be accounted for in any analysis of change due to Glastir options. However, this result does not necessarily mean that the Tir Gofal scheme did not have any long term impacts. At this stage it is more likely to reflect our inability to detect effects given the small sample size available. Hence, based on just years 1 and 2, we do not have enough coincidence between GMEP plots and past Tir Gofal option land to adequately test whether the positive changes seen in grasslands, woodland and blanket bog in Medcalf et al. (2012) are reflected in the GMEP sample. These analyses will have greater power when all four years of data have been accumulated. At that point we will re-run these analyses in preparation for analysing change in time once the second roll starts to yield repeat data.

5.3.4 Application of indicators of Glastir impacts on Section 42 species; characterizing the GMEP baseline

5.3.4.1 Introduction

By definition Section 42 species are rare and many of these taxa are not directly monitored in GMEP. It therefore makes sense to separate the investigation of Glastir impacts on these species into two questions; 1) Does the target species coincide with GMEP 1km survey squares in which linked options are present? 2) By looking at all land under these option bundles even in GMEP 1km survey squares where the target species is absent, is their evidence that options are driving the changes in ecological conditions that would be expected to favour the species if it were present? To answer the first question we have assembled species distribution data at 1km square resolution and overlaid this with GMEP 1km survey squares (see section 5.2.1). To answer the second we have developed proxy indicator variables derived from the GMEP field surveys. Because ecological recording within each GMEP 1km survey square is done at the level of habitats and landscape features, these indicators can be precisely derived for those areas and features targeted by specific options within each GMEP 1km survey square. This greatly increases the sensitivity of analyses but accumulating enough data to adequately test bundles of options relies on enough uptake of each option across GMEP 1km survey squares.

5.3.4.2 Methods

In order to construct proxy indicators for each Section 42 species we start by reviewing the extent to which the likely ecological impact of each Glastir option could be captured by measured changes in attributes recorded in the GMEP field surveys (see Appendix 5.10 and 5.15). In some instance instances these attributes may include direct counts of the target species (see 5.2.4) but in most these attributes centre on measurements of change in extent or condition of habitats and features. The assumption is that the option if implemented correctly will result in enhancement or maintenance of the species population. While we do not question the link between option and species performance it is possible that other factors not altered by Glastir options could result in lack of expected ecological change. Examples include predation of ground-nesting birds where such predation is not directly controlled by Glastir, long term weather effects on animals and plants, species pool depletion, residual fertility and ongoing application of fertilisers, all of which are potential obstacles to the reassembly of plant and invertebrate communities. To identify the likely importance of these additional factors on species performance and to support the prescribed link between each option and ecological impact a literature review was carried out. This focused on each Section 42 species. The reviews are summarized in Appendix 5.15. These also specify the indicator variables drawn from the field survey that will be used to measure the ecological changes expected to result from each option.

5.3.4.3 Results and Discussion

A subset of Section 42 species are associated with their own bundles of Glastir options (Table 5.3.4.3.1). To illustrate the application of the approach, indicators were assembled and applied to baseline data from GMEP year 1 and 2 survey squares (Table 5.3.4.3.2). Species were selected representing Section 42 invertebrates, mammals, birds and plants focusing on those that are more widely distributed in Wales. These baseline assessments characterize the starting point of the rolling program illustrating initial differences between habitats and features in and out of specific options. Whether any significant differences across the baseline are attributable to legacy effects of previous schemes is critical to assess and will be ultimately tested via the inclusion of explanatory variables that classify land in terms of exposure to previous scheme options. Preliminary analyses of years 1 and 2 are presented in 5.3.2 and Appendix 5.2. The analysis will eventually be repeated with the inclusion of years 3 and 4 increasing statistical power.

Target objective	Number of associated Glastir options
Arable Plants	9
Arctic Alpine Plants	7
Barbastelle Bat	57
Bechstein's Bat	53
Black Grouse	11
Brown-Banded Carder Bee	65
Chough	20
Corn Bunting	22
Curlew	17
Dormouse	20
Pearl Mussel	46
Golden Plover	13
Grassland Fungi	32
Great Crested Newt	94
Greater Horseshoe Bat	93
White Fronted Goose	11
Heathland Plants	22
High Brown Fritillary	22
Lapwing	14
Lesser Horseshoe Bat	91
Lichens	40
Marsh Fritillary	27
Pearl Bordered Fritillary	19
Rare Plants	52
Red Grouse	16
Red Squirrel	19
Ring Ouzel	12
Shrill Carder Bee	65
Turtle Dove	24
Twite	38
Water Vole	64
Welsh Clearwing	16

Table 5.3.4.3.1 *Count of Glastir management options linked to each species. Options counted are those “more likely to deliver in a wider range of situations” according to the scheme. Capital works are excluded. Species in red have been used as initial examples of the application of proxy indicator variables. For full details and results see Appendix 5.10 and 5.15. Gwyniad is excluded since it only occurs in Bala Lake.*

Target species	Number of GMEP 1km survey squares with recent species records / number with Glastir species options	Expected indicator variable status in-option versus out-of-option	Consistent with expectation? [3]
Dormouse	0/27	Understorey cover-weighted canopy height higher (broadleaf wood)	NS (2)
		Bramble cover higher (broadleaf wood)	**Yes** (1), NS (1)
		Honeysuckle cover higher (broadleaf wood)	Too few data
		Total tree and shrub richness higher (hedgerows)	NS (2)
Rare Arable Plants	0/16	Annual forb richness higher	No (1) [1]
		Fertility score lower	NS (1)
		Cover of arable crop higher	NS (1) [1]
Curlew	2/29	Vegetation height heterogeneity higher	NS (4)
		Wetness score [2]	NS (4)
		Rush (*Juncus* spp.) cover [2]	NS (4)
		Vegetation height [2]	Not tested
Lapwing	2/27	Vegetation height heterogeneity higher	NS (4)
		Wetness score [2]	NS (4)
		Rush (*Juncus* spp.) cover [2]	NS (4)
		Vegetation height [2]	Not tested
Lesser Horseshoe Bat	5/81	Fertility score lower	**Yes** (1), NS (5)
		Plant species richness higher	NS (6)
		Wetness score higher	NS (6)
Marsh Fritillary Butterfly	6/69	Foodplant cover higher	Too few data
		Grass:forb ratio lower	**Yes** (1), NS(9), No (0)
		Wetness score higher	**Yes** (1), NS(9), No (0)

Table 5.3.4.3.2 *Summary of tests of the difference in indicator values between subsets of plots in or out of Glastir options where these options are associated with enhancement or maintenance of conditions for Section 42 species. Note that these results are preliminary because they include data from years 1 and 2 only. See Appendix 5.10 for full details of the derivation and testing of indicators for each species.*

[1] While arable forb richness would be expected to be higher as a result of the extensifying options included for Rare Arable Plants, the in-option land was found to be still in Improved Grassland prior to ploughing. It is not surprising that arable forb richness was higher in the counterfactual dataset because this comprised out-of-option plots in cultivation.

[2] Whether the values of these indicators should be higher or lower in-option versus out-of-option depends on the values of the observed data because the desired status is not too high nor too low. In these instances, movement toward, or no movement away from, the desired range of values over time yields the expected direction of change over time.

[3] Numbers in brackets indicate the number of data subsets analysed. For example so as to contrast like-with-like, where possible separate analyses were carried out within different Broad Habitats and by plots sampling linear features or areas of habitat away from linear features (see Appendix 5.10).

5.3.4.4 Application and further development of Section 42 species indicators

The large number of options associated with each Section 42 species yields a large number of possible indicator values that can be analysed (see Appendix 5.15). While this level of detail will hopefully be of interest to species experts, ways are needed of summarizing these many results into an aggregated indicator of performance. An option would be to simply count up the numbers of consistent or inconsistent and significant plus non-significant differences in indicator variables across all indicators and species. The danger in so doing is that species-specific details are lost. The advantage is that multiple trajectories of change over many habitats are distilled into a simple, albeit simplistic, aggregate indicator (Smart et al. 2012). Applying the approach to the baseline assessments we can summarise across all indicators for the six target objectives as follows:

Number of Non-significant tests	54
Number of significant differences consistent with expected option impact	4
Number of significant differences NOT consistent with expected option impact	1

This analysis provides the baseline against which future changes will be assessed. Significant differences identify a difference in the baseline condition not actual responses to options. Once repeat data is available the test will be whether the rate of change in time differs between in and out of option habitats and landscape features. We would envisage that a similar summation of trends should be possible to derive.

5.3.4.5 Options and areas of further work

The analyses reported above are preliminary in that they are only based on year 1 and 2 data and only for an example of set of Section 42 species. However we have carried out a detailed assessment of the relationships between options linked to all the species included in Glastir and available field survey data. This has enabled us to identify ecological indicator variables for all options and species (Appendix 5.15). These are numerous and so prior to spending effort applying all these to all species we plan to engage with species experts to determine their views about the ecological importance and sensitivity of the suggested indicators. An outcome of this consultation process could be an agreed set of weightings such that some indicators contribute more than others. This could reflect experts' views about the likely ecological importance of different options independent of their actual area of uptake.

Additional activities could include deriving reference values for indicators associated with habitats, features and landscapes considered optimal on the basis that they are known support healthy, stable populations of Section 42 species. This not likely to be a straightforward process. For example the largest extant populations may well be associated with highly atypical locations where our generalised suite of indicators prove less relevant at highlighting those positive factors present and where equivalent conditions may constitute unrealistic goals for the wider countryside represented in GMEP 1km survey squares.

The most important next step is to establish an increasingly automated workflow where a larger range of indicators for more species and more options are assembled and tested alongside a counterfactual dataset. The variable that exerts the greatest influence on the feasibility of such testing is option uptake across the GMEP sample. By the end of year 4 we will be able to identify a stable pattern of option uptake across species and all GMEP 1km survey squares. These levels of uptake will then determine how many indicator+option+habitat/feature combinations can be meaningfully analysed.

5.3.5 Evidence for associations between breeding birds and Glastir management options

5.3.5.1 Introduction

It is critical to monitor the multiple Glastir options that are aimed wholly or partly at benefiting birds, including conservation-priority species, to ensure that public funds are being spent as effectively as possible. For birds, ultimately, this means measuring responses of population trends to Glastir management (as tested for legacy schemes: Section 5.3.1, see also Baker et al. 2012), but such responses inevitably take several years to occur and to be detectable. In the short-term, tests of the mechanisms through which Glastir is expected to act can be conducted through analyses of bird field data collected under GMEP: habitat managed under Glastir would be expected to be selected by priority species relative to comparable non-Glastir habitat.

5.3.5.2 Methods

The bird surveys in GMEP are designed to provide accurate data on abundance within GMEP 1km survey squares (subject to less stochasticity than the transect counts from national volunteer monitoring under the BTO/JNCC/RSPB Breeding Bird Survey) and also precise bird locations, permitting bird locations to be investigated in respect of small-scale habitat features.
The locations of birds recorded in GMEP 1km survey squares in 2013 and 2014 were mapped digitally using ArcGIS 10. These spatially referenced bird data (omitting flying birds) were then overlain onto maps of habitat types identified from the field survey (Chapter 1) and of Glastir option (Table 5.3.5.2.1) locations. It could therefore be identified whether birds appeared to be selecting Glastir-managed areas of each habitat types. By chance, birds would be expected to be distributed between Glastir and non-Glastir habitat in proportion to their availability, so the difference from this expectation was used as a test of baseline differences between land coming into the scheme and that remaining outside. The habitats considered as the background or baseline for the bird-relevant Glastir options are listed in Table 5.3.5.2.1. Background habitat availability was considered in terms of areas, except for hedgerow management, for which the underlying habitat was considered to be the length of the boundaries between agricultural fields. Birds were considered to be associated with boundaries if they were mapped as being present within 10 metres of an agricultural field boundary.

Birds are highly mobile and the nature of survey protocols means that they are more likely to be recorded during some activities (e.g. singing or flying) than others (e.g. incubating or feeding). It is possible, therefore, that the precise locations of birds in respect of habitat features may be misleading about the importance of local habitat features. For example, a bird may be recorded singing in a given tree because the location had become good breeding habitat after the addition of Glastir management 50m away. Therefore, in addition to testing whether precise bird locations were associated with Glastir management, locations were compared at the GMEP 1km survey square level, asking whether GMEP 1km survey squares with Glastir management were more likely to contain the target species than other GMEP 1km survey squares with similar land-use (Table 5.3.5.2.2). These analyses also included records of birds in flight, which were excluded from the smaller-scale association tests, because association with the habitat at a larger scale can reasonably be assumed for most species in this context.

To date, all analyses have focused on total counts summed across all target species, weighted by the number of visits to each GMEP 1km survey square listed for each option type, and comparing the distribution of these counts between Glastir and non-Glastir areas, either within or between GMEP

1km survey squares. Future analyses will consider species-specific patterns, once more years of data are available.

Option type	**Option(s) included**
Heathland	Management of Coastal and Lowland Heath; Lowland Wet Heath
Hedgerow	Enhanced Hedgerow Management on Both Sides; Hedgerow management - both sides
Marshland	Management of Lowland Marshy Grassland; Management of Lowland Marshy Grassland with Mixed Grazing; Lowland Marshy Grassland; Lowland Bog and Other Acid Mires
Saltmarsh	Management of Grazed Saltmarsh; Management of Grazed Saltmarsh with Mixed Grazing
Winter food‡	Retain Winter Stubbles; Unsprayed Spring Sown Cereals Retaining Winter Stubbles; Unharvested Cereal Headland
Summer food	Fallow Crop Margin; Unsprayed Spring Sown Cereals and/or Pulses; Establish a Wildlife Cover Crop on Improved Land; Unfertilised and Unsprayed Cereal Headland
Woodland	Woodland: Stock Exclusion; Trees and Scrub: Establishment By Planting; Trees and Scrub: Establishment By Natural Regeneration; Scrub: Stock Exclusion; Wood Pasture
Reedbed	Reedbed: Stock Exclusion; Reedbed: Creation
Chough	Grassland Management for Chough (Feeding)
Corn Bunting	Unsprayed Autumn Sown Cereal Crop for Corn Bunting (Nesting and Feeding); Unsprayed Spring Sown Barley Crop for Corn Bunting (Nesting and Feeding)
Curlew	Grassland Management for Curlew (Nesting and Chick Feeding) ; Grassland Management for Curlew (Adult Feeding); Haymeadow Management for Curlew (Nesting)
Golden Plover	Grassland Management For Golden Plover (Feeding)
Lapwing	Grassland Management for Lapwing (Nesting and Feeding); Unsprayed Spring Sown Cereals; Oilseed Rape; Linseed or Mustard Crop For Lapwing (Nesting); Uncropped Fallow Plot For Lapwing (Nesting)
Ring Ouzel	Grassland Management for Ring Ouzel (Feeding)

Table 5.3.5.2.*1 List of Glastir option groups and single options combined in each option group.*

Option type	Species tested	Habitat(s) used for comparison with Glastir
Heathland	Skylark, Tree Pipit, Linnet, Cuckoo, Kestrel, Curlew, Meadow Pipit, Stonechat, Green Woodpecker	Dwarf Shrub Heath
Hedgerow	Linnet, Yellowhammer, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Turtle Dove, Song Thrush	Boundaries between fields identified as Arable and Horticulture, Lowland Calcareous Grassland, Improved Grassland or Neutral Grassland.
Marshland	Reed Bunting, Kestrel, Barn Owl, Curlew, Lapwing, Redshank, Snipe	Blanket Bog, Purple Moor-grass and Rush Pasture, Lowland Raised Bog, Lowland Acid Grassland, Bog
Saltmarsh	Skylark, Twite, Bar-tailed Godwit, Curlew	Coastal Saltmarsh
Winter food‡	Skylark, Linnet, Corn Bunting, Yellowhammer, Reed bunting, Kestrel, Barn Owl, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Starling, Meadow Pipit, Chaffinch	Arable and Horticulture
Summer food	Skylark, Corn Bunting, Yellowhammer, Reed Bunting, Kestrel, Barn Owl, House Sparrow, Tree Sparrow, Grey Partridge, Dunnock, Bullfinch, Turtle Dove, Starling, Song Thrush, Lapwing, Chaffinch	Arable and Horticulture
Woodland	Tree Pipit, Linnet, Yellowhammer, Pied Flycatcher, Spotted Flycatcher, Willow Tit, Marsh Tit, Wood Warbler, Dunnock ,Bullfinch, Song Thrush, Stonechat, Blackcap, Chiffchaff, Redstart, Sparrowhawk, Great Spotted Woodpecker, Whitethroat	Broadleaved Mixed and Yew Woodland, Lowland Mixed Deciduous, Upland Mixed Ashwood, Upland Oakwood
Reedbed	Bittern, Cuckoo, Reed Bunting, Marsh Harrier, Reed Warbler, Sedge Warbler, Swallow	Reedbed
Chough	Chough	Calcareous Grassland, Neutral Grassland, Maritime Cliffs and Slopes
Corn Bunting	Corn Bunting	Arable and Horticulture
Curlew	Curlew	Lowland Hay Meadow, Acid Grassland, Lowland Acid Grassland
Golden Plover	Golden Plover	Lowland Calcareous Grassland, Calcareous Grassland, Upland Calcareous Grassland
Lapwing	Lapwing	Lowland Hay Meadow, Acid Grassland, Lowland Acid Grassland, Arable and Horticulture
Ring Ouzel	Ring Ouzel	Upland Calcareous Grassland, Neutral Grassland

Table 5.3.5.2.2 *Species tested and land-use associated with each option group used to compare association between species and Glastir options.*
‡ Tested only at the GMEP 1km survey square level as winter food could not be directly related to abundance of breeding birds at patch level.

5.3.5.3 Results

A summary of the area of each Glastir option type found in the GMEP 1km survey squares 2013/14 is presented in Table 5.3.5.3.1. Only five options were present within GMEP 1km survey squares: Hedgerow, Marshland, Winter Food, Summer Food and Woodland, although the area of woodland management was less than 2ha. The most widespread management was in the marshland category, with more than 100ha included in GMEP 1km survey squares. Only four of the 14 option types considered were present within GMEP 1km survey squares considered in 2013 and 2014: two of them farmland types, as well as marshland and woodland. None of the species-specific option types was found in GMEP 1km survey squares. Within GMEP 1km survey squares where they were present, option coverage was generally low, except for marshland management, which covered up to around half of a 1km square (Table 5.3.5.3.2).

Management option group	Total option area (ha) (length (m) for hedgerow)	Sum of area of suitable habitat in Glastir square outside relevant option (ha) (length (m) for hedgerow)	Sum of area of suitable habitat across all GMEP 1km survey squares with no relevant option (ha) (length (m) for hedgerow)	Total habitat area (ha) (length (m) for hedgerow)
Heathland	0	0	525.18	525.18
Hedgerow	3,946.94	46,391.41	490,126.90	1,752,976.41
Marshland	144.11	94.15	1041.71	1,279.97
Saltmarsh	0	0	1.90	1,082.44
Winter food	NA	NA	460.05	479.78
Summer food	6.79	12.94	460.05	479.78
Woodland	1.87	0.59	772.56	775.02
Reedbed	0	0	14.27	14.27
Chough option	0	0	2,397.8	2,397.8
Corn Bunting option	0	0	479.78	479.78
Curlew option	0	0	1,293.48	1,293.48
Golden Plover option	0	0	8.88	8.88
Lapwing option	0	0	1,773.27	1,773.27
Ring Ouzel option	0	0	2,388.06	2,388.06

Table 5.3.5.3.1 *Habitat and option areas. Winter Food was tested* only at GMEP 1km survey square *level as it could not be directly related to abundance of breeding birds at patch level.*

Option group	Number of GMEP 1km survey squares with non-zero area	Mean area of relevant option per GMEP 1km survey square (ha) (length (m) for hedgerow)	Min area (ha) (length (m) for hedgerow)	Max area (ha) (length (m) for hedgerow)	LCI (ha) (length (m) for hedgerow)	UCI (ha) (length (m) for hedgerow)	Sum of total option area (ha) (length (m) for hedgerow)
Hedgerow	8	493.36	58.61	1758.62	29.37	957.35	3946.94
Marshland	18	8	0.21	52.95	1.65	14.36	144.11
Summer food	6	1.13	0.003	3.37	0	2.44	6.79
Woodland	2	0.93	0.86	1.02	0	1.95	1.87

Table 5.3.5.3.2 *Summary of option groups with non-zero area within GMEP 1km survey squares.*

The breakdown of individuals of target species and the number of GMEP 1km survey squares in which options in each group were found are presented in Table 5.3.5.3.3. The rarer species for which there are bespoke options in Glastir were only recorded rarely: three were not recorded at all, reflecting their rarity or range-restriction. The exceptions were Chough, Curlew and Lapwing, which, were recorded in three, one and five GMEP 1km survey squares, respectively. Good numbers of birds of the target species for the other, more general options were found in GMEP 1km survey squares, but most option types were rare in the sample and few target birds were associated with the option areas. Only management of Marshland registered target species in more than one GMEP 1km survey square.

Ultimately, given sufficient sample sizes, these data should be sufficient to support formal statistical tests of the selection of Glastir-managed habitat relative to the availability of the background habitat. Currently, this is only possible for marshland, for which 16 of the 19 individuals of the target species were found in Glastir-managed habitat; this shows a statistically significant positive association with Glastir, by area (χ^2_1=8.89, P<0.05).

When the numbers of target species found in GMEP 1km survey squares with each Glastir option type were considered (Table 5.3.5.3.3), target species were found in GMEP 1km survey squares featuring three Glastir option types (Marshland, Summer food and Woodland).

Management option group	Number of individuals of target species associated with management option	Number of GMEP 1km survey squares with non-zero management area (number of which also with target species)	Number of individuals of target spp associated with suitable habitat across all GMEP 1km survey squares	Number of GMEP 1km survey squares with relevant habitat (number of which also with target species)
Heathland	0	0	551	54 (35)
Hedgerow	0	8 (0)	625	119(92)
Marshland	16	18 (6)	62	118 (21)
Saltmarsh	0	0	66	89 (18)
Winter Food	NA	NA	247	51 (35)
Summer food	4	6 (1)	247	51 (33)
Woodland	1	2 (1)	1,547	117 (96)
Reedbed	0	0	48	4 (3)
Chough option	0	0	4	125 (3)
Corn Bunting option	0	0	0	51 (0)
Curlew option	0	0	3	81 (1)
Golden Plover option	0	0	0	2 (0)
Lapwing option	0	0	8	116 (5)
Ring Ouzel option	0	0	0	125 (0)

Table 5.3.5.3.3 *Summary of Glastir option categories and associations with target birds. All figures are sums across 2013 and 2014 GMEP 1km survey squares.*

The individually targeted species were mostly not associated with the background habitats deemed broadly suitable for them, reflecting the target species' rarity or range-restriction. The exceptions were Curlew and Lapwing, which, were recorded in one and five GMEP 1km survey squares, respectively.

When the numbers of target species found in GMEP 1km survey squares with each Glastir option type were considered (Table 5.3.5.3.1), four Glastir option types (Marshland, Winter food, Summer food and Woodland) were associated with target species.

A summary of option areas in GMEP 1km survey squares, omitting squares with zero area, is presented in Table 5.3.5.3.2. Marshland was the most widespread option, present in the highest number of GMEP 1km survey squares and covering the widest area (as much as half of a 1km square) across all GMEP 1km survey squares. Two of the other three options (Summer food and Woodland) had been recorded in five or fewer squares, whilst option for the management of hedgerows was present in eight GMEP 1km survey squares (Table 5.3.5.3.2) but they all typically covered/extended for only small areas/stretches of land.

As well as numbers of individuals associated with Glastir management, it is possible that birds respond in respect of relative densities, with more being supported per unit area of habitat once it is managed under Glastir. A comparison between the densities of target birds found in patches of relevant options and those in the relevant background habitat elsewhere within the same GMEP

1km survey squares is presented in Table 5.3.5.3.2. Two options, Marshland and Summer Food had higher overall densities of birds within the habitat entered into the option than outside of it, whilst Woodland management had considerably lower densities associated with the Glastir option than the background habitat.

The comparison between densities of birds found in appropriate habitat in GMEP 1km survey squares with and without some relevant Glastir management is also presented in Table 5.3.5.3.4. When the entire GMEP 1km survey square with Glastir management was considered, densities of birds where there was relevant Glastir management nearby were considerably higher in all three option groups for which target birds were recorded in GMEP 1km survey squares with the options: Marshland, Summer food and Woodland. Note that sample sizes here were small (Table 5.3.5.3.1), but formal statistical tests will be possible once more data are available.

Option	Density of birds per 10 ha (or per 10m of agricultural boundary) in relevant habitat within Glastir squares		Density of birds per 10 ha (or per 10m of agricultural boundary) of relevant habitat across entire GMEP 1km survey squares:		Number of birds of target species in:	
	In Glastir option patches	Outside Glastir option patches	With Glastir options	Without Glastir options	Glastir squares	Non-Glastir squares
Heathland	0	0	0	2.34	0	123
Hedgerow	0	0.007	0.007	0.01	33	592
Marshland	1.11	0.32	0.79	0.04	19	4
Saltmarsh	0	0	0	0	0	0
Winter Food	NA	NA	1.01	1.95	2	90
Summer food	5.89	1.54	3.04	1.74	6	80
Woodland	5.35	16.94	12.80	5.01	2	387
Reedbed	0	0	0	11.91	0	17
Chough option	0	0	0	0.01	0	4
Corn Bunting option	0	0	0	0	0	0
Curlew option	0	0	0	0.02	0	3
Golden Plover option	0	0	0	0	0	0
Lapwing option	0	0	0	0.03	0	5
Ring Ouzel option	0	0	0	0	0	0

Table 5.3.5.3.2 *Comparison between density of birds (including flying individuals) of relevant target species for each Glastir option group and that expected in suitable habitat outside of Glastir within GMEP squares. Higher density of target species associated with relevant Glastir management compared to suitable habitat are underlined.*

5.3.5.4 Discussion

There is an indication that the Glastir options for marshland management, woodland management and the option group designed to provide food to farmland birds in summer may be attracting higher densities of individuals of target species than are found in the relevant background habitats. However, formal statistical tests have not been conducted because the sample sizes are currently too small, so this result should be interpreted with caution. In particular, over a third of Marshland management was present in only one square (53 ha). More generally, it is important to note that associations between birds and management in this analysis will not prove positive effects of Glastir. They could also show that Glastir has been adopted disproportionately in areas of higher quality habitat; however, the results could then be interpreted as showing the extent to which Glastir has been targeted effectively. In this way, the results of the present analysis add to those measuring targeting efficacy using Bird Atlas 2007-11 data that are currently in progress and will be reported in September 2015.

Nine of the 14 option types considered could not be tested because they have yet to be found in GMEP squares. Others were limited by small sample sizes. This partly reflects the rarity of some management types, but partly also reflects the targeting of the GMEP sample in 2013 and 2014, which aimed to cover management providing water- and carbon-related ecosystem services. With larger sample sizes after further years of GMEP, it is to be expected that more tests will be possible and that the power associated with the tests that have been conducted will increase, but it should be noted that direct targeting of this management, or of the background habitats in which it is found, may be necessary before sample sizes that support strong analyses of effect are achieved. Winter management requires winter survey data to test associations because even resident birds can move considerable distances between seasons. Winter bird surveys have been conducted during 2014-15 and will report in March 2016; note, however, that many winter-relevant Glastir options are rare and it is highly unlikely that analysable data will be obtained without several years of winter survey, given the current prioritization for Targeted sampling.

5.3.6 Does habitat diversity vary according to whether land is in Glastir?

Within Glastir high habitat diversity as such is not an objective of the scheme but maintaining areas of habitat land in good condition is important. It is a useful measure to assess whether land in and out of Glastir consist of higher habitat diversity at this stage of the scheme.

5.3.6.1 Methods

Habitat diversity was calculated as described above. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect.

5.3.6.2 Results

Habitat Diversity is higher in 1km squares that are subject to Glastir management.

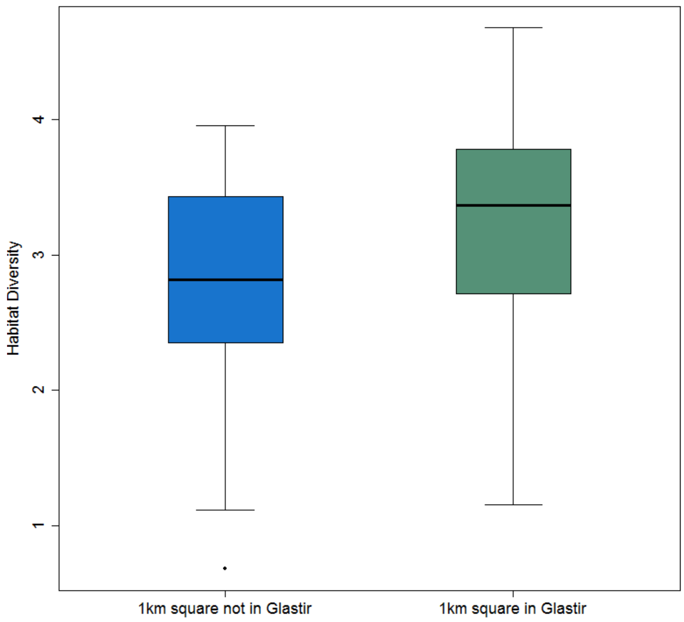


Figure 5.3.6.2.1: *Mean Habitat diversity per 1km square where land is managed under Glastir and is not in Glastir.*

Table 5.3.6.2.1: *Mean Habitat diversity per 1km2 in a 1km square where land is in Glastir and land is not in Glastir*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	2.815193	2.549823	3.080562
1	3.185736	3.042068	3.329405

There is a significant difference between squares where the land owner is in Glastir and squares where the land owner is not in Glastir

5.3.7 What is the relationship between Habitat diversity and other diversity indicators?

5.3.7.1 Background

As mentioned previously it is generally assumed that habitat diversity is a good thing to promote within a landscape, many species benefit from a mosaic of habitat types providing different functions. High habitat diversity should provide resilience from changing environmental conditions (e.g. climate change) enabling species to move between habitats when conditions change. For the habitat themselves high habitat diversity could provide resilience or it could be a sign of increasing fragmentation. The relationship between habitat diversity and the number of characteristic plant species (Common standards monitoring) was tested.

5.3.7.2 Method

Habitat diversity was calculated as before in GMEP 1km squares. The number of Characteristic plant species was calculated as mentioned in section? Using species identified by experts for the JNCC and updated with lists from the BSBI. The number of CSM species within each vegetation plot was calculated, then for this analyses a total number of CSM species within a 1km square was derived.

5.3.7.3 Results

There is a significant positive relationship between habitat diversity and the number of characteristic plant species within a 1km square. This is evidence that habitat diversity is a good thing in that there are more habitat types but they consist of characteristic plant species indicators of condition in the habitat.

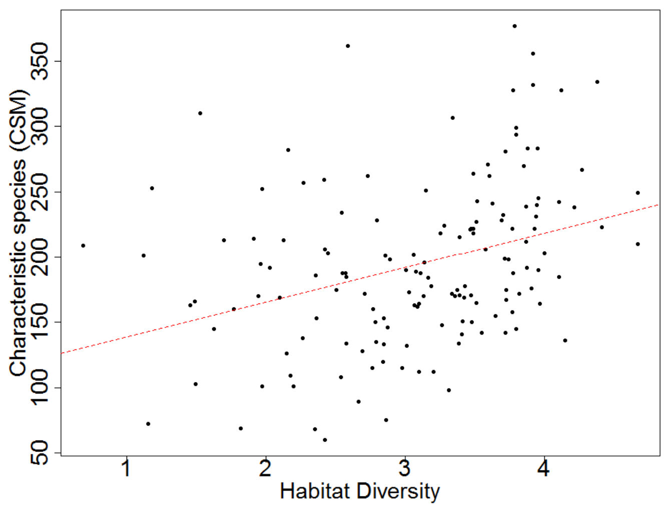


Figure 5.3.7.3.1 *The relationship between Habitat diversity (1km square) and the number of characteristic habitat species (CSM indicators).*

There is a positive relationship between Habitat diversity and Characteristic plant species ($p<0.001$)

5.3.8 Does habitat connectivity of wetlands vary according to whether land is in Glastir?

Habitat fragmentation is a threat to biodiversity by both reducing the total area of habitat available and by reducing connectivity between habitat fragments. Habitat connectivity is the ability for species to move between areas of habitat and is a function of the number and size of habitat patches and how close together they are. Many, large habitat patches which are close together will have higher connectivity and would be expected to support higher biodiversity. Habitat connectivity has been estimated for two different habitats recorded in GMEP squares; broadleaf woodland (see woodland chapter) and wetland. Both of these habitats have been targeted by Glastir prescriptions which aim to increase the total area of habitat; these prescriptions would be predicted to lead to an increase in habitat connectivity.

To assess the potential for Glastir prescriptions to increase connectivity of wetland it is important to know the initial level of connectivity within each GMEP square. The number, size and distance between habitat patches are estimated from the habitat maps recorded by the field survey team. The method used for assessing the connectivity of wetland in GMEP squares is to calculate the Euclidean distances between habitat patches. This is simply the distance in metres between the edges of each habitat patch (termed Euclidean distance because it follows the rules of Euclidean geometry). The Euclidean distance between all habitat patches in GMEP squares was calculated for wetland in ArcGIS 10.2 (ESRI, Redlands, CA, USA) using the Conefor Inputs GIS extension (Jenness Enterprises, Flagstaff, AZ, USA).

To convert the pairwise distances between each of the habitat patches into a metric of habitat connectivity the Probability of Connectivity was calculated using the Conefor program (Saura & Torné, 2009). The Probability of Connectivity (PC) metric is the probability that two individuals of a species randomly occurring in the landscape (in this case the GMEP square) are in habitat patches that are interconnected, given the distribution of habitat patches and the ability of the species to disperse across the landscape[1]. To look at the relative differences between GMEP survey squares the results were scaled so that the square with the highest PC metric had a value of 1.

Wetland was defined as any habitat falling under the broad habitat classifications of Fen, Marsh Swamp or Bog. This included several priority habitats e.g. Fen and Blanket bog. It was assumed in the calculations that species could move freely between fen and bog habitats, this may not be the case in reality and therefore connectivity may be overestimated. From the sample of year 1 and 2 GMEP survey squares, 104 contained some wetland and had a connectivity index of above zero. As with broadleaf woodland there were no differences in the relative connectivity index (PC scaled to between 0 and 1) between squares in and out of the Glastir scheme or between targeted and wider wales squares (Figure 5.3.8.1). Again, the distribution of values showed that most squares had low connectivity, with only a few squares being highly connected.

[1] The model was parameterised with a dispersal distance of 200 metres and a probability of 0.5. These are arbitrary choices but serve to illustrate the variation in connectivity between squares.

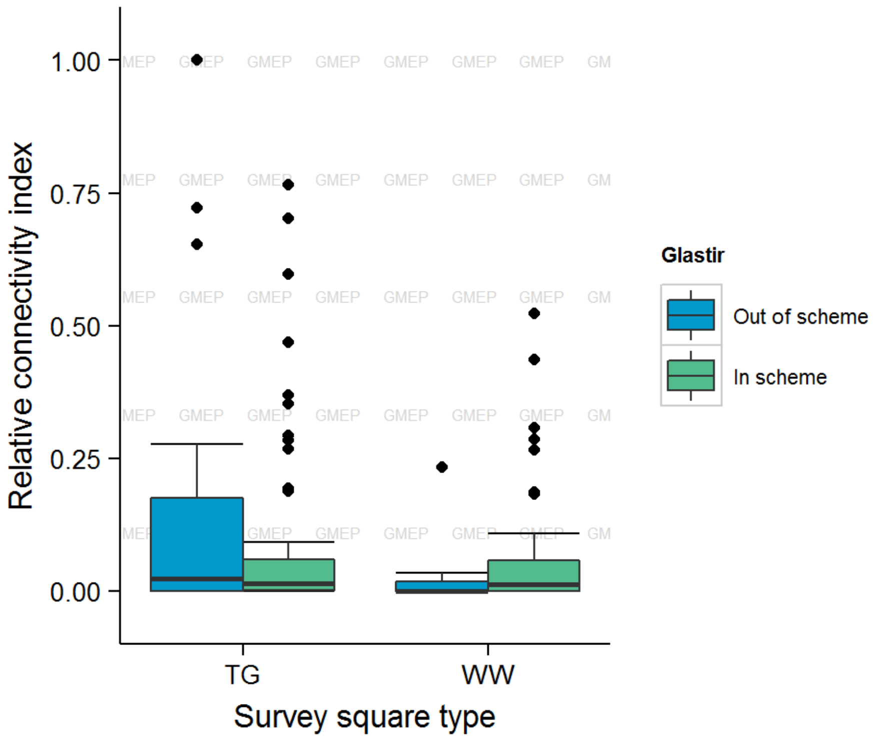


Figure 5.3.8.1. *Connectivity of wetland habitats in Year 1 and 2 GMEP survey squares. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.010	0.043	0.156
Not in Glastir	0.076	0.011	0.141

5.4 Remote sensing applications

A large amount of new work has been carried out in the past year using remotely sensed data in combination with GMEP survey data and biological records. The objectives of this work are principally to explore ways in which satellite derived products can be combined with field survey data and other data products to develop new capacity for predicting attributes and quantities of interest across Wales outside of the 1km survey squares. New results have been produced in three areas.

1. Application, comparison and analysis of Land Cover Map with other survey products has been carried out in support of the objective to identify and map HNV land in Wales. This work is fully described in the HNV chapter in this report (Chapter 9).
2. Testing whether satellite imagery can be calibrated against finely resolved field survey data to produce predictive maps of ecosystem function at fine resolution outside of survey squares. This work is in its early stages and is reported in Appendix 5.14. Using a dataset of independent GB site measurements and plant trait composition a regression model was produced predicting above-ground Net Primary Production (ANPP) in terms of cover-weighted Specific Leaf Area. This was used to estimate ANPP for GMEP vegetation plots and these estimates were then compared with remotely sensed NDVI values for pixels containing the field plots. The strength of this relationship (r-sqrd=0.53 to 0.71) justified interpolating the relationship to produce a finely resolved predictive map of ANPP for Wales. Primary Production is a fundamental measurement of ecosystem function and further work will progress the validation of our initial model and explore further relationships with ecological attributes and natural capital across Wales and within survey squares.
3. See also the development of a fine resolution Woody Cover Product (WCP) in Chapter 4 which captures small-scale woody features such as hedgerows and small patches of trees. These provide valuable ecosystem services and are important for biodiversity conservation.

5.5 Future work; priorities for years 3 and 4

- Ongoing campaign to gain further access to updated species distribution records at 1km square resolution.
- Consultation and dialogue with species experts to explore and develop the proxy indicators for Section 42 species.
- Extension and development of proxy indicator approach so that it can be automatically and flexibly applied given Glastir uptake levels in year 3 and 4 squares.
- Consultation and dialogue with NRW to explore representativeness of Priority Habitat mapped areas and their vegetation quadrats.
- Production of high-level biodiversity indicators.
- Production of national estimates of Priority (Section 42) Habitat extent where possible.
- Ongoing development of up and downscaling approaches to provide interpolated biodiversity estimates outside of GMEP squares and thus to provide new datasets for quantification of biodiversity and characterization of HNV land across Wales.

5.6 Acknowledgements

We thank Claire Carvell (CEH Wallingford), Trevor Dines and Cath Shellswell (Plantlife) and Lisa Hundt (Bat Conservation Trust and the UK Bat Steering Group) for expert advice on species requirements and species distribution data.